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EPA (Environmental Protection Agency) Field Guide for Scientific Support Activities Associated with Superfund Emergency Response

Battelle Pacific Northwest Labs., Richland, WA

Prepared for

Corvallis Environmental Research Lab., OR

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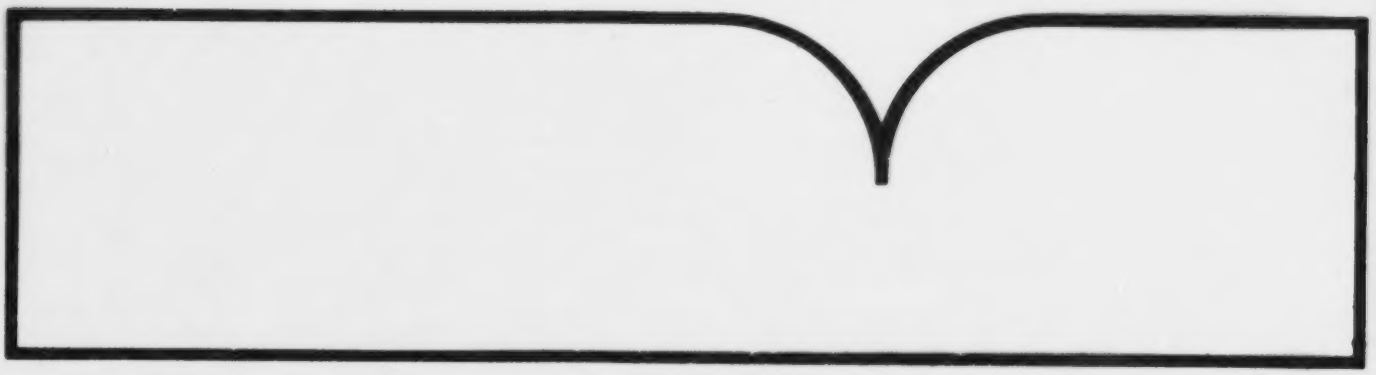

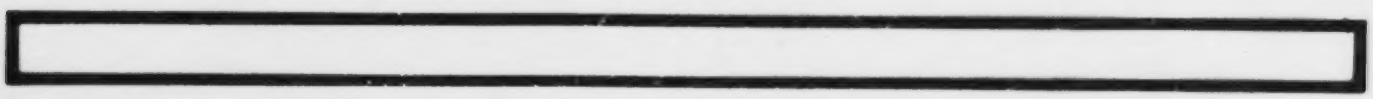

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The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) grants the President the authority to respond to releases of hazardous chemical substances that imminently and substantially threaten public health or welfare, or the environment. The Act, which establishes a $1.6 billion Superfund to finance response actions, and which charges the Environmental Protection Agency with administering critical portions of the response program was designed to build on the existing environmental response authority given to EPA under Section 311 of the Clean Water Act During an emergency response to a release of a hazardous substance, the On-Scene Coordinator will require scientific information for the decision-making process. This manual provides guidance in establishing and maintaining scientific support for responses to such releases. The manual delineates the methods and technical aspects of scientific support required during implementation of Superfund removal activities, regardless of the government unit (state, local or Federal) that may be performing the implementation. Although comprehensive in coverage, the primary emphasis is on environmental effects on inland areas. Pre-response activities are emphasized. Consultantants, scientific literature, computer data bases, records and analytical capabilities must be identified and appropriate contracts or other agreements must be arranged before an emergency response. Region-specific resources must be identified.

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EPA FIELD GUIDE FOR SCIENTIFIC SUPPORT ACTIVITIES ASSOCIATED WITH SUPERFUND EMERGENCY RESPONSE

Prepared for
Emergency Response Division
Office of Emergency and Remedial Response
U. S. Environmental Protection Agency

Prepared by
Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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DISCLAIMER

This manual describes the scientifically relevant and important functional activities that concern regional, state, and local authorities during the response to hazardous substance releases. It is intended to convey technical recommendations only and not to constitute agency policy. The manual should not supersede specific procedures and documentation for quality assurance, chain-of-custody, and other requirements addressed by Environmental Protection Agency regulations and policy guidance documents currently in effect. The research described in this report has been funded by the United States Environmental Protection Agency through interagency agreement no. AD-89-F-2A115 to the United States Department of Energy. This report has been subjected to the Agency's required peer and policy review.

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Corvallis, Oregon 97333

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PREFACE

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) grants the President the authority to respond to releases of hazardous chemical substances that imminently and substantially threaten public health or welfare, or the environment. The Act, which establishes a $1.6-billion Superfund to finance response actions, and which charges the Environmental Protection Agency (EPA) with administering critical portions of the response program, was designed to build on the existing environmental response authority given to EPA under Section 311 of the Clean Water Act.

Releases are defined under CERCLA as any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of a substance into the environment, except 1) those resulting in exposure in a work place (only to employees who may have a resulting claim against their employer), 2) emissions from certain classes of engine exhausts, 3) those of certain classes of radioactive materials, and 4) normal applications of fertilizer. The environment is defined as all lands; waters (ground, surface, and ocean); soils and substrata; and ambient air within or under the jurisdiction of the United States. Public health or welfare concerns all factors affecting human health and welfare, including the natural environment, fish, shellfish, wildlife, public and private property, and shorelines and beaches.

Hazardous substances include certain named materials plus such materials that, when released into the environment, may present substantial danger to the public health, welfare, and the environment. Hazardous substances do not include crude oil; petroleum or petroleum products (except for those named); or natural gas, natural gas liquids, or synthesis gas usable for fuel. Under CERCLA, releases are other than those permitted under provisions of the Clean Water Act (Federal Water Pollution Control Act), the Solid Waste Disposal Act, the Safe Drinking Water Act, the Clean Air Act, the Atomic Energy Act (or regulations promulgated thereunder), or the release of materials authorized under applicable state laws for the purpose of stimulating or treating wells for the production or enhanced production of crude oil, natural gas, or water. Furthermore, for the purposes of this document, releases are those requiring response to prevent, limit, or mitigate an emergency in which risk to public health or welfare or the environment exists.

ACKNOWLEDGMENTS

Pacific Northwest Laboratory (PNL) operated by Battelle Memorial Institute for the U.S. Department of Energy prepared this document. The work was performed under interagency agreement no. AD-89-F-2A115 with the U. S. Environmental Protection Agency (EPA) Office of Research and Development, Corvallis Environmental Research Laboratory, Corvallis, Oregon. The work was performed at the request of the EPA Office of Emergency and Remedial Response. Dr. Lawrence C. Raniere was the EPA Project Officer and Dr. Richard A. Craig was the PNL Project Manager. PNL staff performing the work were N. E. Bell, J. G. Droppo, C. J. English, P. J. Gutknecht, G. R. Keizur, B. K. Marshall, G. L. McKown, J. M. Meuser, and M. A. Parkhurst. In preparing this document, technical input and guidance was solicited from and given by Emergency Response Program staff of each of the EPA Regional Offices. These regional personnel were also given the opportunity to provide a technical review of the document. Technical review and guidance have been provided by Karen Burgan, Sherry Hawkins, and Mark Mjoness of the Emergency Response Division and Richard Stanford of the Remedial Response Division of the EPA Office of Emergency and Remedial Response.

In addition, technical peer reviews were provided by Dr. Jay Rodstein of the National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, and Dr. Thomas Winter, United States Geological Survey, Denver. Dr. Royal Nadeau, Environmental Impact Section, Region II, EPA also provided an in-depth review.

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EXECUTIVE SUMMARY

During an emergency response to a release of a hazardous substance, the On-Scene Coordinator (OSC) will require scientific information for his decision-making process. This manual provides guidance in establishing and maintaining scientific support for responses to such releases. The manual delineates the methods and technical aspects of scientific support required during implementation of Superfund removal activities, regardless of the government unit (state, local, or Federal) that may be performing the implementation. Although comprehensive in coverage, the primary emphasis is on environmental effects on inland areas.

Pre-response activities are emphasized. Consultants, scientific literature, computer data bases, records, and analytical capabilities must be identified, and appropriate contracts or other agreements must be arranged before an emergency response. The identification of region-specific information (e.g., land-use maps, identification of the habitat of rare or endangered species, locations of wells) should be included in the library resources.

The response to a release can be divided into three activities (during each of which scientific support may be required): 1) characterization, 2) assessment, and 3) mitigation. Characterization entails the determination of the nature and extent of the release as well as of possible pathways to sensitive communities. Assessment involves the analysis of the rates of transport to the sensitive communities, the effect of the release on those communities, and the effect of mitigative actions. Mitigation entails applying the best cleanup actions and appropriate follow-up activities.

An important element of the characterization phase is the identification of the substances involved in the release and their physical and chemical characteristics. In addition, information is needed concerning the extent of the contamination, the fate of the chemicals (partially determined by their volatility, stability, biodegradability, sorptive properties, bio-accumulation properties), the physical properties of mixtures of chemicals, and the reactivity of the released materials.

An important element of the assessment phase is the calculation of the transport rate of the materials released to sensitive populations via surface water, ground water, or air. Thus, a knowledge of meteorology (for atmospheric transport and precipitation) and of hydrology (for surface-water and ground-water transport) may be required. Data sources for meteorological information include weather stations, computer models, and consultants experienced in their use.

Surface releases can run off to surface water, or penetrate to ground water. Surface flow is dictated by geography and by the existence of sufficient material to maintain flow. Information concerning surface-water transport is provided by appropriate maps that identify local topography, water courses, and manmade structures. Government agencies or consultants can provide interpretation of flow data (as obtained from surface-water stream gages) to predict transport times.

In the case of a surface release, the transit time to ground water depends on local geography and hydrology. A knowledge of the existence of conduits to ground water or of impermeable layers is necessary to understand whether ground-water transport of a surface release would provide a pathway to man. Subsurface releases may initially be detected in ground water. In these cases, information on the extent of contamination may be obtained by sampling existing wells or by drilling and sampling new wells. Data on ground-water flow can be acquired from measures of ground-water potential gradients and through the use of appropriate models.

The potential hazard presented by a release is determined by the concentrations reaching sensitive populations. In the case of airborne transport, the entire population may be affected; the size and distribution of this population is available from land-use maps. For surface-water transport, the critical locations are the drinking-water withdrawal points or reservoirs. These locations should be identified in advance from water-supply companies or other sources. For ground-water transport, the population using well water from a contaminated aquifer is at risk. Information on ground-water use can be obtained from water suppliers, public health departments, and well drillers, among others.

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The location of sensitive nonhuman populations in the area (including Federal and state rare and endangered species) should be determined. The U.S. Fish and Wildlife Service provides information on Federally listed rare and endangered species. Locations of state-listed species are maintained by state departments of natural resources. This information, too, should be gathered in advance. Because the mitigative action chosen by the OSC may have effects on indigenous wildlife (not just on rare and endangered species), data on these populations should be available. This information can be gathered in advance from state departments of natural resources or game departments.

Another element in analyzing the hazard posed by the release is the effect of the extant concentrations on exposed populations. Thus, toxicological properties and thresholds for the various toxicological responses must be known. Sources of pertinent data include handbooks and computer data bases.

Finally, a mitigation process itself will affect the environment. Thus, the OSC must recognize potential negative consequences associated with alternative mitigation measures. Depending on the nature of the response and on the measures adopted, these consequences may include: transfer of the hazardous materials to different ecological units, hazards to on-scene personnel, or the formation of secondary products endangering sensitive populations.

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1.0 INTRODUCTION

The response to a release or threat of release of hazardous chemical substances includes actions taken to prevent, minimize, or mitigate damage to public health or welfare or the environment. The response process includes measurement, assessment, or evaluation activities necessary to determine the potential damage to public health or welfare or to the environment; measures to limit access to the contaminated area; removal and disposal of released substances; possible provision of alternative water supplies; confinement, diversion, containment, segregation, neutralization, destruction, treatment or incineration, recycling, or reuse of contaminated materials; repair or replacement of damaged containers; collection of leachate and runoff; and dredging or excavation. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), which establishes a Superfund to finance response actions, broadly defines two types of responses: removal and remedial action. Removal refers to relatively short-term responses, whereas, remedial action indicates responses of considerable duration that are "consistent with permanent remedy." The selection and implementation of response activities is the responsibility of the On-Scene Coordinator (OSC), who bases his scientifically informed decisions on measurement, assessment, and evaluation activities.

Scientific activities take on greater meaning in view of recent trends toward application of scientific principles in evaluating cleanup alternatives, as opposed to "cookbook" approaches. This emphasis implies a more active role for scientific input before, during, and after a response action. As a corollary, it also implies that greater thought be given to the caliber and timeliness of scientific support activities.

The primary purpose of this manual is to provide guidance in establishing and maintaining scientific support for responses to releases of hazardous substances. The manual delineates the methods and technical aspects of scientific support required during implementation of Superfund activities, regardless of the government unit (state, local, or Federal) that may be performing the implementation. The manual provides guidance for development of procedures for acquiring technical support during responses to releases of hazardous substances. As a source book for background information, the document provides:

- information regarding the nature of scientific support needed during response
- information regarding the coordination of general scientific support information concerning technical areas where guidance may be required
- specific reference and source materials, formats, checklists, and methodologies.

The manual is divided into three sections. Section 2 describes the response process and activities performed therein. Section 3 elaborates on the need for scientific support during the response and defines the types of scientific support required. Section 4, entitled "Technical Information" is itself divided into two parts: fundamental technical information and specific regional information. Fundamental technical information refers to basic physical laws, properties, and processes that are universally applicable. This section includes information on chemical characterization; hydrology and meteorology; ecology; toxicology, health, and safety; and impact analysis of mitigation methods. The specific regional information section identifies specific individuals, agencies, and industries within a particular geographic area and their potential assistance during a response to an emergency. Also included are formats that may be used to locate and assemble this information. The individual sections in the manual are color-coded. (Refer to the Contents page for the color-code of a particular section.)

2.0 RESPONSE TO RELEASES OF HAZARDOUS SUBSTANCES

Emergency responses to releases of hazardous substances are composed of two parts: a fast and efficient response effort culminating in control or stabilization of a situation threatening public health or welfare or the environment, and a methodical response effort that considers the incident in relation to the larger environmental (chemical, geological, ecological) picture, regarding both short-term and long-term impacts. The former element is the province of existing emergency response plans; the latter is more the realm of preplanned, well-coordinated scientific support. Responses consist of three basic steps:

- **Characterization**—the acquisition, compilation, and processing of data to describe the scene so that a valid assessment of alternative actions can be made.
- **Assessment**—an analysis of the severity of an incident; the evaluation of possible response actions for effectiveness and environmental impact.
- **Mitigation**—the implementation of the best response action and followup activities.

Because scientific support will be important in each of these steps, each is considered in greater detail in the following sections.

CHARACTERIZATION

The decision for any response action is based on data describing the release of hazardous substances into the environment. The ultimate success of the assessment and mitigation methods depends on accurate, valid data that characterize the materials released, the environmental media affected, and the susceptibility of the environment to harmful effects. Unfortunately, the characterization phase may receive inadequate attention in an emergency situation because of the compelling need to proceed as quickly as possible to an assessment and a mitigation activity. This is why the elements of scientific support, and the coordination of such efforts, are important during the characterization phase.

An idealized flowchart/decision diagram for the characterization phase is shown in Figure 2.1. Experienced response personnel may recognize the logical sequence for approaching a response, even though the entire scheme may require only a matter of hours, or minutes, in an emergency situation. Some of the reasoning may even occur subconsciously; certainly for experienced people many of the steps become almost second nature. This is both good and bad: often in emergencies only the outstanding details can be considered; on the other hand, critical details sometimes can be ignored, or not sufficiently considered.

To assure that details (particularly those regarding data acquisition, completeness, and validity) are adequately considered, the following must be developed:

- a search system, an interpretation mechanism, and documentation center for all technical data; a repository to which the OSC can turn when responses are needed to technical questions or statements such as:

  "Where is the file of data on the chemical properties of these materials?

  "What is the effect of this stuff on carbon steel tanks?

  "One of our guys just stepped in something; find out the toxicological properties and the immediate medical advice."

  "Do we have the necessary background samples from that stream before we divert this stuff into it?"

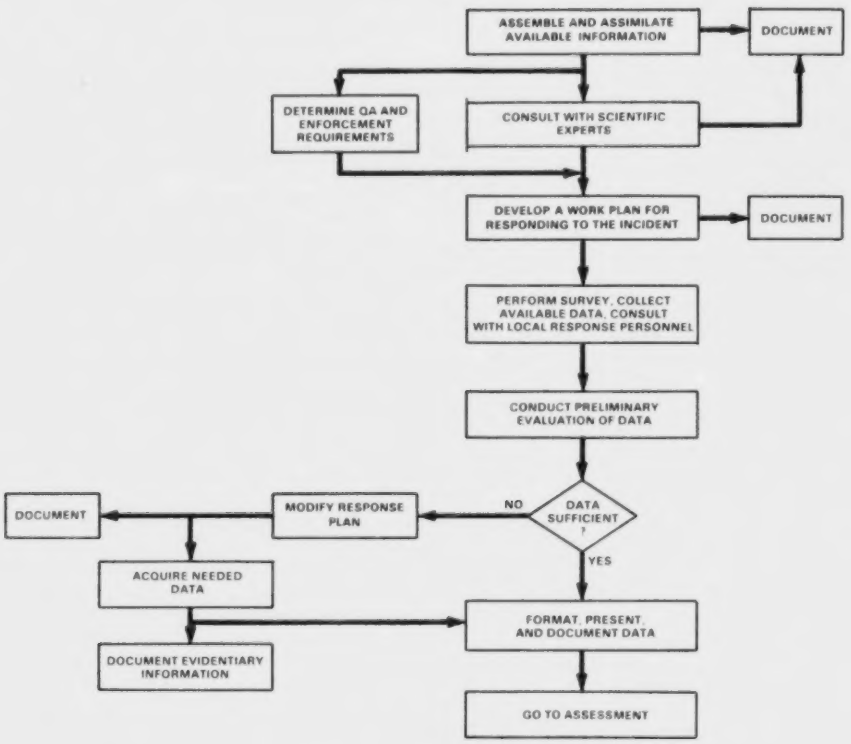

FIGURE 2.1 Characterization Phase

"How valid is this ground-water data we got from the Corps?"

"What do we know about potential vegetation kill if we allow this stuff to spread?"

- a formal planning effort for the acquisition of data, so technical requirements will be met. The objectives of a study must be predetermined, and a plan of action developed to meet those objectives.
- formal documentation and custody functions related to technical information. Not only must data be valid, but the basis for data validity (from technical and legal viewpoints) must be known and defensible as well. The response team should be able to provide the lawyers with an evaluation, based on documented results, of the validity of the data used as legal exhibits.

Acquiring Data

Obviously, in emergency situations the planning effort may need to be expedited. Work plans will often be developed on the way to the airport, or on-scene as the fire is burning or as the material is being absorbed by the ground. Such plans may be recorded in haste and changed many times, but this does not detract from their utility or necessity. The planning should be as complete as is practical, representing the best efforts possible under the circumstances.

A data acquisition plan must consider the following questions:

- Has the situation changed significantly since the last plan was developed?
- What data are needed? What questions need to be answered by a data acquisition effort?
- Is this the best plan to provide needed data in the time allowed?
- What procedures are to be used? Will the data be made available in time to use them?
- Does implementation of the plan interfere with subsequent response-related efforts?
- What are the contingencies if the situation changes?
- What effect will changes in plans have on accomplishments to date? Will these changes invalidate previous work?

Data acquisition and plan development are iterative processes. Because situations may change drastically as response activities proceed, a flexible planned approach is essential.

Technical Questions

In addition, the characterization phase generally involves supplying answers to the following queries:

- What are the substances involved in an incident? What are their physical, chemical, and toxicological properties? How are they to be detected and analyzed?
- What are the quantities involved? What is containing the material that has not been released? What is the leak rate? How should sampling be carried out?
- How are the substances distributed in the environment? What media (air, water, soil, ground water) are affected?
- Where are the materials going? What are the transport mechanisms? What information will be required to determine rates through the various affected media? What transformations and dilutions occur?
- What information will be needed to determine the toxicological effects on the susceptible populations in terms of dosage vs time?
- What residual concentrations are allowable?

Relationship of Technical Information Sections to Characterization Activities

The technical information sections (colored pages) provide information on how and where the physical, chemical, and toxicological properties of the substances can be identified during characterization activities. Furthermore, the Chemical Characterization Section provides information on how to choose the appropriate tests to determine the substances involved in the release. Other technical information sections provide information on how to determine the relevant transport processes, the parameters required to perform the assessment, and the identification of critical human and other populations.

ASSESSMENT

During the time between characterization of the incident and the application of mitigation measures, a series of analyses and decisions must be undertaken to define the extent of the problem and the array of possible response actions. These decisions, and the comparisons and evaluations that lead to them, constitute the assessment phase. Compared to characterization, this phase is less of an exact science; it is here that any rigorous theory of response actions would break down.

Scientific support is required during the assessment phase for concerns such as impact assessment, the levels of cleanup needed, and the calculation of risk and risk reduction. Few guidelines are available to help resolve these concerns; thus, controversies, biases, and alternative approaches will abound. Coordination of technical support activities is necessary, and in turn may be very demanding. The timing of emergency situations increases the difficulty of the assessment significantly.

A diagram of the response activities included in the assessment phase is shown in Figure 2.2. Frequently, several series of parallel efforts culminate at a major decision point. Scientific support needed during this phase includes:

- coordinating the various parallel technical efforts in time and in technical content
- generating specific supporting evidence to aid the decision-making process
- incorporating the evidence in tradeoff analyses
- determining the impact of a decision before it is made
- providing justification and documentation of decisions
- providing support for ancillary or follow-up efforts not directly associated with the mitigation process. (For example, long-term monitoring and restoration activities are not directly a part of the response process, but may be necessary in a particular instance. While such activities may be the province of agencies outside the response network, the response unit may need to help develop and monitor the activities.)

Technical Questions

The assessment phase generally involves supplying answers to queries such as:

- How can a "no-action" alternative be justified and monitored? What follow-up studies would be necessary? What are the potential impacts?
- When will the materials reach a susceptible population? How long before action is required? What are the exposure concentrations as functions of time?
- What are the short-term ecological impacts? What is the impact by species? Are endangered species involved? Are particularly sensitive environmental areas involved?
- What are the long-term ecological impacts (loss of habitat, ecological imbalances, effects of residuals)?
- To what level must cleanup be effected? What are the tradeoffs (risk vs residuals) for different degrees of cleanup (according to the procedures defined by the National Contingency Plan)?
- What is the risk reduction of alternative actions? Are there economic benefits to be gained through a more complete cleanup?
- What restoration will be required? Will an area recover naturally, and if so, how long will it take?
- What documentation (for legal and technical purposes) is necessary for rejected alternatives?
- How can radically different processes be ranked in terms of effectiveness? Is there a cost factor, and how significant should it be?
- What are the side effects and ultimate products from application of an alternative? Is the cure worse than the original problem?

As stated earlier, these are difficult questions that are not amenable to simple solutions or calculations. A coordinated approach backed by as much expertise as possible is recommended.

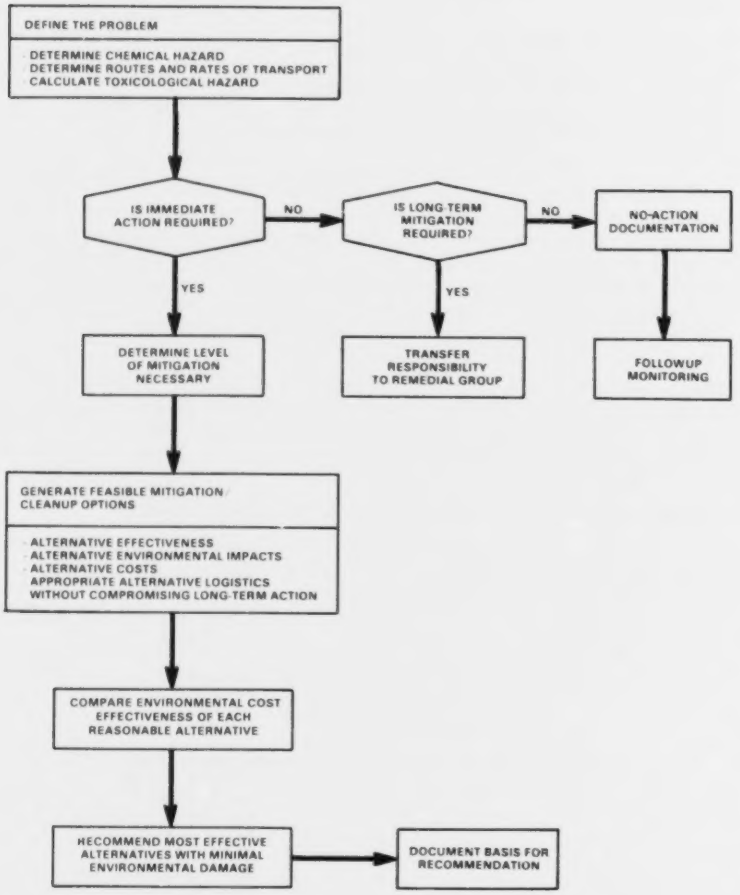

FIGURE 2.2. Assessment Phase

Relationship of the Technical Information Sections to Assessment Activities

The technical information sections provide information on how and where to find assistance in performing assessment activities. These activities include determining the effects of the no-action alternative and the effects of possible mitigation methods. Discussed are needs for, and scientific aspects of, calculating transport rates through various media.

MITIGATION

Mitigation plans are frequently developed by engineering and contractor personnel under the supervision of the OSC. An idealized flowchart/decision diagram for the mitigation phase is shown in Figure 2.3. Mitigation efforts follow directly from the assessment phase, and do not involve much scientific support activity. However, technical observation and assistance as an adjunct to cleanup operations is required. This is obvious in two areas:

- **Certification**—The response team will be required to certify that mitigation is complete and sufficient to stabilize a release situation. This requires continuing attention to ecological and geophysical impacts as a response action proceeds. Each situation differs and application of proven mitigation methods does not in itself assure entirely predictable results. Observations of hydrological, chemical, and ecological parameters during the cleanup must continue, and an overall evaluation must follow cleanup procedures. These data become an important part of the response documentation, both for scientific and enforcement reasons.

- **Monitoring**—Scientific information may be needed to design, implement, and supervise a surveillance and monitoring system that functions long after the response effort ceases. This system assures that solutions continue to be adequate and indicates whether additional efforts are required. S·h activity also includes attention to restoration of areas damaged by a release.

Relationship of Technical Information Sections to Mitigation Activities

The technical information sections provide information to help the OSC identify potential consequences of mitigation methods. These sections also can help the OSC acquire the technical and scientific resources to certify and document mitigation activities.

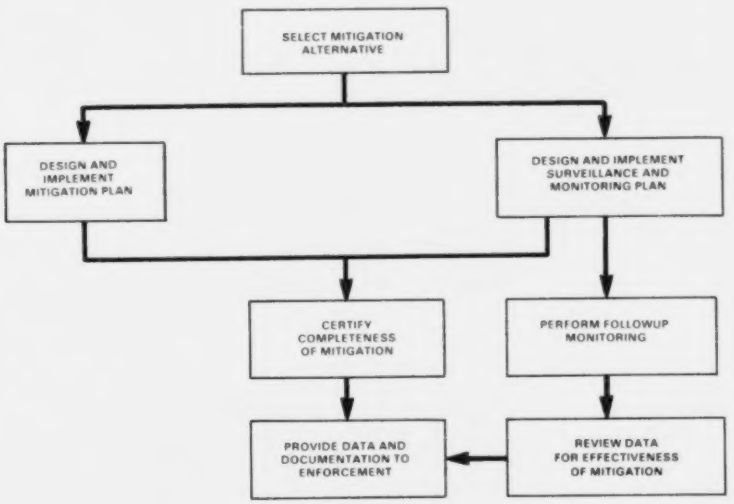
SELECT MITIGATION ALTERNATIVE
DESIGN AND IMPLEMENT MITIGATION PLAN
DESIGN AND IMPLEMENT SURVEILLANCE AND MONITORING PLAN
CERTIFY COMPLETENESS OF MITIGATION
PERFORM FOLLOWUP MONITORING
PROVIDE DATA AND DOCUMENTATION TO ENFORCEMENT
REVIEW DATA FOR EFFECTIVENESS OF MITIGATION

FIGURE 2.3. Mitigation Phase

3.0 SCIENTIFIC SUPPORT

Scientific support during a response to a hazardous release comes from many sources (Federal, state, local, and private), all of which must be coordinated to be useful to on-scene personnel. Information required by the OSC may be very specific, or it may be general, requiring broad, technical, and interdisciplinary approaches to a problem. Successful coordination and responsiveness requires a well-maintained technical contact network and familiarity with scientific references and data sources.

An integrated team approach to scientific support, whether organized by one person or implemented by several staff members who use the system, can result in rapid access to, and efficient use of the information required. Such a system, however, must be developed before an incident occurs and maintained by use and continued contact. Establishing and maintaining this network assures the desired support and allows for continuity between related, or similar, responses.

The role of scientific support in the response process dictates that specific activities be performed before, as well as during an incident. In addition, certain actions may require post-operative support.

PRE-OPERATIVE DEVELOPMENT OF SCIENTIFIC SUPPORT

Pre-incident planning increases the availability of timely scientific information and guidance to the OSC. The development of a scientific support network before or between incidents is the cornerstone of well-defined, accessible information and support during a response. This network comprises individuals and agencies, as well as a repository for documents and data bases.

A system of knowledgeable contacts ensures that requests for aid are made to appropriate individuals or agencies. A first step in this direction is the identification of potential technical experts/advisors in a variety of disciplines. The responsible staff can generate an initial list, which can be expanded as contacts are made. Scientists who will provide assistance may be found in Federal, state, and local government agencies, in universities, and in industry. Nationally recognized experts and scientists within the region should be contacted. Such individuals should be members of the Regional Response Team (RRT).

Once identified, the individuals should be contacted to clarify their area of expertise and to discover their degree of willingness to provide assistance. Some may wish to aid in on-scene response, whereas others may prefer to provide information via telephone. Continued contact will promote information exchange and feelings of cooperation, especially when an emergency cry for help comes during nonworking hours.

Contractual agreements should be negotiated during these preresponse contacts when appropriate. The agreements may be with individual experts, or they may be for general services that need to be available immediately. A list of these should be compiled and made readily available to all response personnel.

A second aspect of planning for scientific support is the compilation of regionally appropriate references or data. Certain technical information that is universally applicable (such as that found in the references of each technical information section of this manual) should be augmented by data specific to the region. Necessary information includes the identification of vulnerable resources or critical habitats requiring special protection, baseline data for these resources, industries operating in the region and the chemicals most used by these, commercial transportation routes, and hazardous substance disposal sites. Environmental regulatory limits of pollutants, health criteria, and enforcement or quality assurance requirements should also be included. This compilation should contain a listing of available field equipment needed to support reconnaissance studies, as well as reports on all response actions in the region, whether led by EPA or other agencies.

Advances in research and development should be routinely reviewed for applicability to response actions. The response team should have at its disposal state-of-the-art knowledge in technical areas and on the status and results of research projects, especially those initiated by problems raised at other incidents.

Because many of these preparatory functions overlap, an integrated scientific support program is needed. Once contacts have been made and information amassed, a program must be established for using these resources. The first step is to develop the scientific support portions of a Regional Contingency Plan. Ways to acquire the required technical information through experts should be specified for planning, response, and post-response activities. Interfaces among EPA, the RRT, natural resource trustees, and university and industrial scientific communities should be established. In addition to a Regional Contingency Plan, a Regional Response Center (RRC) library should be established and maintained, with the information synthesized and cross-referenced. One possible visual format for presenting a large amount of information is through over-lay base maps. Baseline data, drinking-water well locations, types of industry, historical incident locations, industrial chemical use, and transportation routes are examples of data suitable for cartographic presentation. Also contained in the central library, as well as in each RRT library, should be the preplanned list of contacts (a directory of expertise) that includes individuals and institutions to be notified or consulted in the event of an incident.

Possible formats for this formidable task of contact, coordination, and compilation are provided in the Specific Regional Information Section of this manual. Although establishing and maintaining such a system is time consuming, once in place it will provide efficient access to the required expertise as well as continuity from site to site.

OPERATIONAL ACCESS TO SCIENTIFIC SUPPORT

The function of scientific support during an incident is to assimilate preplanned material and necessary additional scientific information into operational decision making for which the OSC is responsible. This pertains to environmental aspects of the OSC's decisions regarding identification, containment, removal, and disposal of the hazardous material involved. The nature of scientific support required will vary with the type, location, and severity of the incident. It may include:

- sampling and analyzing the materials involved and their quantities, both for response action and subsequent legal purposes
- trajectory modeling for the prediction of the movement of the material in a given time frame and for the locations that would be affected
- defining the relevant toxicological aspects
- analyzing other aspects of the behavior and fate of the hazardous substance, including any alteration in physical and chemical characteristics that may be expected under various environmental conditions
- projecting probable environmental impacts of various cleanup strategies and selecting the least harmful containment techniques
- predicting public health and ecological effects of acute discharges
- identifying threatened natural resources, critical habitats, and sensitive populations
- establishing priorities for protecting affected populations, including wildlife rehabilitation requirements
- assuring data validity and proper interpretation, both for operational and enforcement purposes.

The OSC may acquire this support directly or, during large and complex responses, may request coordination of the scientific support by another individual. When this coordination function is delegated, the designated scientific support coordinator (SSC) is responsible to the OSC. The SCC is the liaison between the OSC and the scientific community, relating requests for and offers of assistance, as well as integrating and interpreting the advice from experts.

POST-OPERATIVE SCIENTIFIC SUPPORT

Some scientific activities may continue after the completion of cleanup activities. Damage assessment, restoration necessitated by cleanup activities or by intrusion of the hazardous substance into the environment, public health studies, and long-term monitoring may be undertaken by a governmental agency, industry, or a private institution. Whether sponsored by EPA or by other agencies, if possible, these activities should be monitored by the individual who coordinated the scientific support. This could ensure that all pertinent data would be available for conducting the studies and that the results would become part of the information base in the RRC library.

At the termination of a response, regardless of which specific scientific support functions are used during the incident, the individual coordinating the support activities should verify that all actions (successful or not) are completely documented. This full documentation, or a record of where it exists, should be available to appropriate participating organizations.

Scientific support activities constitute a dynamic system. The activities that enhance the basic knowledge and response capability of the response team aid the OSC during a specific incident. Conversely, the experience at one incident expands the working knowledge of the response process, making the lesson of experience available to all the OSCs.

4.0 TECHNICAL BACKGROUND INFORMATION

As discussed in Section 3.0, the OSC will require technical information to make a risk-based assessment of the release situation and the mitigation alternatives. This includes information on: 1) characterization of the material involved in the release, 2) the potential for transport of the material, 3) the size and character of potentially affected human (and other) populations, 4) the potential hazard to exposed populations posed by the material, and 5) the potential effects of emergency response procedures.

In the following sections we describe the type of information that may be required and indicate where this information may be obtained. No attempt is made to reproduce all of this information because much of it will be region-specific. Rather, a guide for acquiring this knowledge is provided. Emphasis is placed on pre-emergency acquisition of information and data sources.

Because the decisions of the OSC during an emergency situation may become an issue in a later enforcement action, all technical information should be documentable (and documented). If sampling is required, the sample should be representative and significant in a statistical sense. Observations of the "undisturbed" environment may be important to an enforcement action.

The technical background information sections deal with the following areas:

- Chemical Characterization—applicable to characterization phase
- Hydrology and Meteorology—applicable to characterization and assessment phases
- Ecological Assessment—applicable to characterization and assessment phases
- Toxicology, Health, and Safety—applicable to characterization, assessment, and mitigation phases
- Impact Analysis of Mitigation Methods—applicable to assessment and mitigation phases
- Region-Specific Information—applicable to characterization, assessment, and mitigation phases.

For ready reference, each subject area is printed on a specific color of paper. Reference sources for each category are included with each section. A checklist of activities to be performed before or between, during, and after responses is provided at the beginning of each section.

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4.1 CHEMICAL CHARACTERIZATION ACTIVITY CHECKLIST

ACTIVITIES BEFORE OR BETWEEN RESPONSES

1. Obtain a list of the chemicals and hazardous materials most likely to be involved in spills or emergencies (see p. 4.8).
2. Obtain handbooks and chemical data references and become familiar with their use (see pp.4.7, 4.16, 4.19-21).
3. Become familiar with the use of computerized data bases such as OHM-TADS and obtain the necessary equipment to use this source at the response scene (see p 4.8).
4. Establish contacts with local experts and consultants who can be contacted on short notice to obtain needed data. Maintain file of consultants' phone numbers (see p. 4.8).
5. Become familiar with analytical and sampling techniques that may be needed during responses (see pp. 4.9-16)
6. Assemble necessary sampling equipment, including a supply of prepared sample containers and packing and shipping materials (see p. 4.14).
7. Obtain necessary equipment for field analytical methods and become familiar with their use (see pp. 4.14-15).
8. Obtain a list of local analytical laboratories and become familiar with their shipping requirements, turn-around times, and available methods. (see p. 4.14).

ACTIVITIES DURING RESPONSE

1. Document the chemical data needed during these responses, to assist in critiquing response activities.

ACTIVITIES FOLLOWING RESPONSE

1. Critique response activities and identify where improvements in chemical characterization can be made. If necessary, revise checklist.

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4.1 CHEMICAL CHARACTERIZATION DATA FOR EMERGENCY RESPONSE

An understanding of the chemical characteristics and behavior of contaminants is vital if a response to an emergency is to be effective. Chemical data must be obtained which allow the response team to take the following steps:

1. Identify the chemical contaminants present.
2. Determine the extent of chemical contamination.
3. Determine the need for chemical analyses.
4. Determine if chemical contaminants will react during response activities and, if so, with what.
5. Predict behavior of contaminants in the environment during and after response.
   - Will they volatilize?
   - Will they degrade?
   - Will they sorb to soil?
   - Will they bioaccumulate?

Identify the Chemical Contaminants Present

Identifying the chemicals involved in an emergency is a vital first step in selecting appropriate response actions. Identification may take place in several increasingly refined steps, depending on urgency. For example, appearance and odor may be used to make an on-scene identification of an unknown material (e.g., benzene or a derivative). Such information would be adequate to initiate emergency response actions. Later, exact determination of the material's identity could be obtained from laboratory analyses. Methods of identifying chemicals are discussed on pages 4.7-8.

Determine the Extent of Chemical Contamination

The extent of contamination (the quantity of materials and geographic area involved) must be known for the magnitude of the problem to be adequately assessed. As with chemical identification, the determination may take place in several steps. For example, an order of magnitude estimate may be all that initially is required to assure that an adequate number of response personnel are called out. Later, more refined determinations may be necessary to design specific response actions. Means of determining the extent of contamination are discussed on pages 4.8-9.

Determine the Need for Chemical Analyses

Chemical analyses may be necessary to determine the identity of chemicals or the extent of chemical contamination. In some cases, such as the occurrence of a seep of unknown material from an area where a variety of wastes had been buried, chemical analyses may be the only means of identifying the contaminants present. Analytical methods are often limited by time, costs, and the availability of equipment. Under emergency conditions the use of many analytical methods, though desirable, may not be possible because of these constraints. Analytical methods and factors affecting their use, are discussed on pages 4.9-16.

Determine If Chemical Contaminants Will React During Response Activities and, If So, With What

Knowledge of chemical reactions is especially important in selecting appropriate response actions. Inadvertent chemical reactions caused by response actions can have disastrous results. For example, water has been applied to leaking tanks of silicon tetrachloride to control hydrogen chloride emissions, resulting in a violent reaction and even greater

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production of hydrogen chloride. Knowledge of reactions is also extremely important in selecting containers and materials for use in response. For example, stainless steel is nonreactive with concentrated sulfuric acid, but will corrode when contacted with dilute sulfuric acid (such as the residuals from cleanup of a sulfuric acid spill). Means of determining reactivity are discussed on pages 4.16-17.

Predict Behavior of Contaminants in the Environment During and After Response

Once released to the environment, contaminants can undergo a variety of physical and chemical transformations. Knowledge of these transformations is valuable in determining response actions and judging the environmental persistence of contaminants. Important transformations and environmental pathways are identified below.

Volatilization—Volatilization is an important means by which some chemicals disperse through the environment. Volatilization rates can influence the selection of response techniques and are valuable for judging the environmental persistence of contaminants. For example, trichloroethane is a common industrial solvent having high volatility. A land spill of this material might well be expected to volatilize before cleanup could be accomplished. Knowledge of volatilization rates would also allow response personnel to determine that trichloroethane flushed into a sewer probably would be volatilized during the treatment process and not discharged with the effluent. Methods of determining volatilization rates and the chemical data required for such determinations are discussed on page 4.17.

Degradation—Common degradation modes for environmental contaminants are hydrolysis, photolysis, chemical oxidation, and biodegradation. Degradation rates are extremely useful for determining the environmental persistence of contaminants. This knowledge is valuable for determining response actions. For example, acrolein is a common industrial chemical that can be explosive and can emit hazardous vapors when heated. Emergency use of water spray to control this hazard may be undesirable, however, because of the possibility of runoff and the extreme toxicity of acrolein to aquatic life. Knowledge of acrolein's relatively rapid degradation rate in water could prove helpful to the response team in determining a course of action. Means of obtaining degradation rates and the chemical data required for such determinations are discussed on page 4.18.

Sorption—Sorption of chemicals to soils and sediments can retard the movement of contaminants, affecting response decisions. For example, formic acid moves rapidly through the soil; thus, ground-water contamination would be very probable following spills in areas of shallow ground water. The pesticide, parathion, however, is strongly sorbed to soil and would not be expected to move to ground water. Different degrees of soil sorption might result in different response actions following spills of these two materials. Methods of determining sorptive properties and the chemical data required for such determinations are discussed on page 4.18.

Bioaccumulation—Bioaccumulation is an important factor in assessing the seriousness of environmental contamination because it is a good indicator of possible long-term exposure of populations to contaminants. Contaminants that bioaccumulate can concentrate in the food chain, causing concern long after emergency response and cleanup

Predict Behavior of Contaminants in the Environment During and After Response (contd)

efforts are over. The possibility of bioaccumulation may influence the choice of response actions. For example, exceptional steps might be taken to prevent a highly bioaccumulative material such as pentachlorophenol from entering the food chain following a release. Such steps might not be taken with a substance such as phthalic anhydride, which exhibits no tendency to bioaccumulate. Methods of determining bioaccumulation potential and the chemical data required for such determinations are discussed on page 4.18.

METHODS FOR OBTAINING REQUIRED CHEMICAL DATA

Identify the Chemical Contaminants Present

Identification of chemical contaminants present at an emergency can be made by the following means:

- records
- observable characteristics
- analyses.

Records—Records can provide the most rapid, positive identification of the materials involved at an emergency and, if available, should be the preferred means of identification. A variety of useful records (e.g., shipping papers and transportation labels) are now required when transporting hazardous materials. Records of specific materials are not required on domestic waterborne shipments. Although general categories and quantities are available, these general records are of limited use in planning an emergency response. A complete description of available records and how to use them in identifying spilled material is provided by Huibregtse et al. (1977). Also, the Association of American Railroads is developing a computerized tracking system for rapidly identifying railcars containing hazardous materials. This system is described by Guinan (1980). The Association of American Railroads also supports an emergency response communication system known as HAMER. This system is capable of linking emergency response personnel with the shipper, the supplier, the manufacturer, and scientific experts through voice and hard copy communications. The use of records to identify chemicals present at uncontrolled waste sites is much more difficult. Waste manifests, which describe each shipment of waste received at a facility, are a possible source. In many cases, however, these have only recently been required.

Observable Characteristics—Observable characteristics such as odor, color, density, and reaction may be useful in rapidly identifying an unknown material. Though this approach may be limited to identifying a general class of chemicals rather than specific compounds, it has the advantage of being speedy. An excellent method of rapidly identifying spilled materials based on easily observable characteristics is presented in the *Field Detection and Damage Assessment Manual for Oil and Hazardous Materials Spills* (EPA 1972). Over 300 hazardous materials are identified by odor, color, reaction, etc.

The U.S. Coast Guard Chemical Hazard Response Information System (CHRIS) Manuals CG-446-1 and CG-446-2 (USCG 1974a and 1974b) describe observable characteristics of approximately 900 hazardous chemicals. The OHM-TADS data system maintained by EPA can be

Identify the Chemical Contaminants Present (contd)

used to identify chemical substances based on observable characteristics. Physical properties of the unknown material (physical state, odor, color, turbidity, miscibility, reactions) are input to the computer system, which then performs a search to obtain possible identities. The OHM-TADS system contains data on approximately 850 chemicals and hazardous substances.

Contacts within the chemical industry should prove helpful in identifying chemicals or wastes based on physical descriptions. The Chemical Manufacturers Association (CMA) Chemical Transportation Emergency Center (CHEMTREC) telephone hotline (800-424-9300 or 483-7616 in Washington, D.C.) is a means of contacting such people. This center maintains a directory of industry experts who can be contacted for information related to emergency response. CHEMTREC can rapidly provide information on approximately 18,000 chemicals and trade-name products.

Analyses—Analytical methods may be necessary to identify unknown chemical contaminants. In emergency conditions where rapid response is required, the available techniques may be limited to the qualitative field methods described on pages 4.14-15. Qualitative and quantitative laboratory methods described on pages 4.9-13 may be used if adequate time is available.

Preparing for Emergencies—To prepare for rapid identification of spilled materials, scientific support staff should first obtain a list of hazardous materials most likely to be involved in local emergencies. For example, DOT records can be reviewed to identify which hazardous materials are transported locally in large volumes. A review of local chemical industries should also help identify materials that may be released to the environment. National Pollutant Discharge Elimination System (NPDES) permits and Spill Prevention, Control and Countermeasures (SPCC) plans would be good sources of this information. Staff should become familiar with the materials identified and learn where specific data useful for identification may be obtained in a hurry. Analytical methods suitable for each chemical also should be identified. The references described in this section should be obtained, especially the *EPA Field Detection and Damage Assessment Manual* (EPA 1972) and CHRIS Manuals CG-446-1 and CG-446-2 (USCG 1974a and 1974b). Provisions should be made to use the OHM-TADS system during emergencies. A computer terminal with acoustical coupler could be obtained so that the OHM-TADS computer could be used at an emergency. Alternately, information from the OHM-TADS files can be obtained on microfiche and a portable reader can be obtained for field use. Also, experts should be contacted who can be available at any time of day or night who might be able to identify substances based on descriptions of smell, appearance, shape, and size of container. Potential contacts could be found with local universities, the chemical industry, and technical assistance teams (TAT) and regional response teams (RRT). Directories of possible contacts are also available through trade organizations and professional societies. One such directory is the *Hazardous Waste Services Directory*, published by J. J. Keller and Associates, Inc (1980). Phone numbers of contacts should be kept on file for emergency use. Staff should also become familiar with the analytical methods described on pages 4.9-14 that can be used for chemical identification.

Determine the Extent of Contamination

Methods of determining the quantities of chemicals involved in an emergency and the areal extent of contamination are similar to those used to identify chemicals. Extent of contamination can be determined by the following means:

- records
- observable characteristics
- analyses.

Records—The transportation records described on page 4.7 contain information on the quantities of hazardous materials transported, and can be used to estimate the quantities of chemicals involved in emergencies.

Observable Characteristics—The same characteristics used to identify unknown materials may be used to determine the extent of contamination. Also, sizes of common shipping and storage containers can be obtained from manufacturers and used to visually estimate quantities of materials involved. Aerial photography and remote sensing may be used to determine areal extent of contamination on a larger scale. This approach allows for quick assessment of contamination of large areas of land and for detection of contamination that might not be visible to the observer on the ground. The U.S. EPA Environmental Monitoring Systems Laboratory (EMSL), Las Vegas, Nevada, and its field station, the Environmental Photographic Interpretation Center (EPIC), Warrenton, Virginia, can provide additional information related to the use of aerial photography and remote sensing in contaminant assessment. Many remote sensing techniques are available. The applicability of each, however, depends on the specific situation; EMSL and EPIC can advise which technique would be appropriate. Also, EMSL and EPIC can provide aerial photographs of an emergency scene within 24 hours.

Analyses—Analytical techniques may provide information on the extent of contamination in a manner similar to their use in identifying contaminants. Most of the analytical methods described on pages 4.9-16 can be used for this purpose. Qualitative chemical methods would be used for determining the areal extent of contamination, whereas quantitative methods would be needed to determine the actual amount of contamination present. A disadvantage of analytical techniques is that they may require extensive sample collection.

Preparing for Emergencies—The suggestions given on page 4.8 for preparing for emergency identification of chemicals also apply to determining the extent of contamination. In addition, scientific support staff should become familiar with the capabilities and availability of aerial photography and remote sensing as they apply to assessing contamination.

Determine the Need for Chemical Analyses

The analytical chemistry support obtained during an emergency response will depend on the objectives of the analyses (i.e., identification, detection, or quantification); the time and money available to perform analyses; and the analytical equipment available. Various analytical methods are discussed below.

Determine the Need for Chemical Analyses (contd)

Instrumental Analyses—Instrumental methods commonly used for analysis of hazardous chemicals are gas chromatography (GC), high-performance liquid chromatography (HPLC), gas chromatography/mass spectrometry (GC/MS), atomic absorption spectophotometry (AA), and inductively coupled argon plasma spectrometry (ICAP). Characteristics of these methods are summarized on Tables 4.1 and 4.2.

Gas chromatography and high-performance liquid chromatography are techniques for quantitative measurement of specific organic materials. These methods are not suited to qualitative identification of unknown materials in a sample; rather, they are best used for measurement of materials known to be present. They can be relatively expensive and time consuming, but are able to analyze in the ppb (parts per billion) range. Although these methods require sophisticated equipment and highly trained operators, advances in mobile laboratories have made bringing this equipment to the field possible. Also, portable GCs suitable for field use are now being produced.

TABLE 4.1 Summary of EPA-Approved Analytical Methods for Organics

Analytes	EPA Method Number	Method Type	Average Cost, $/Sample	Analysis Time, hr
Purgeable Halocarbons	601	GC	130(a)	6 to 12
Purgeable Aromatics	602	GC	150(a)	6 to 12
Acrolein/Acrylonitrile	603	GC	110(a)	6 to 12
Phenols	604	GC	200(a)	6 to 12
Benzidines	605	GC	220(a)	6 to 12
Phthalate Esters	606	GC	110(a)	6 to 12
Nitrosamines	607	GC	150(a)	6 to 12
Organochlorine Pesticides and PCB's	608	GC	110(a)	6 to 12
Nitroaromatics and Isophorone	609	GC	210(a)	6 to 12
Polynuclear Aromatic Hydrocarbons	610	HPLC or GC	310(a)	6 to 12
Haloethers	611	GC	120(a)	6 to 12
Chlorinated Hydrocarbons	612	GC	160(a)	6 to 12
2,3,7,8-TCDD	613	GC/MS	170(a)	~24
Purgeables	624	GC/MS	500 to 800(b)	~24
Base/Neutrals, Acids, and Pesticides	625	GC/MS	500 to 800(b)	~24

(a) Average cost reported in 44 Federal Register, 69462, Monday, 3 December 1979.

(b) Average costs obtained from private analytical laboratory, January 1982.

Note: From guidelines proposed for the National Pollutant Discharge Elimination System (NPDES) permits, for state certifications, and for compliance monitoring under the Clean Water Act (33 U.S.C. 1251 et seq.).

TABLE 4.2 Approved Analytical Procedures for Hazardous Materials

Compound	Sample Handling Class/Fraction	Non-GC Methods	Measurement Techniques (See Note Below)		
				Conventional	
			GC/MS	GC	Detector[a]
Acetonitrile	Volatile	—	8.24	8.03	NSD
Acrolein	Volatile	—	8.24	8.03	NSD
Acrylamide	Volatile	—	8.24	8.01	FID
Acrylonitrile	Volatile	—	8.24	8.03	NSD
Benzene	Volatile	—	8.24	8.02	PID
Benz(a)anthracene	Extractable/BN	8.10 (HPLC)	8.25	8.10	FID
Benzo(a)pyrene	Extractable/BN	8.10 (HPLC)	8.25	8.10	FID
Benzotrichloride	Extractable/BN	—	8.25	8.12	ECD
Benzyl chloride	Volatile or Extractable/BN	—	8.24 8.25	8.01 8.12	HSD ECD
Benz(b)fluoanthene	Extractable/BN	8.10 (HPLC)	8.25	8.10	FID
Bis(2-chloro-ethyoxymethane)	Volatile	—	8.24	8.01	HSD
Bis(2-chloroethyl)-ether	Volatile	—	8.24	8.01	HSD
Bis(2-chloro-isopropyl)ether	Volatile	—	8.24	8.01	HSD
Carbon disulfide	Volatile	—	8.24	8.01	HSD
Carbon tetra-chloride	Volatile	—	8.24	8.01	HSD
Chlordane	Extractable/BN	—	8.25	8.08	HSD
Chlorinated dibenzodioxins	Extractable/BN	—	8.25	8.08	ECD
Chlorinated biphenyls	Extractable/BN	—	8.25	8.08	HSD
Chloroacetalde-hyde	Volatile	—	8.24	8.01	HSD
Chlorobenzene	Volatile	—	8.24	8.01 8.02	HSD PID
Chloroform	Volatile	—	8.24	8.01	HSD
Chloromethane	Volatile	—	8.24	8.01	HSD
2-Chlorophenol	Extractable/BN	—	8.25	8.04	FIC,ECD
Chrysene	Extractable/BN	8.10 (HPLC)	8.25	8.10	FID
Creosote	Extractable/BN	—	8.25(b)	8.10	ECD
Cresol(s)	Extractable/A	—	8.25	8.04	FID,ECD
Cresylic acid(s)	Extractable/A	—	8.25	8.04	FID,ECD
Dichlorobenzene(s)	Extractable/BN	—	8.25	8.01 8.02 8.12	HSD PID ECD
Dichloroethane(s)	Volatile	—	8.24	8.01	HSD
Dichloromethane	Volatile	—	8.24	8.01	HSD
Dichlorophenoxy-acetic acid	Extractable/A	—	8.25	8.40	HSD
Dichloropropanol	Extractable/BN	—	8.25	8.12	ECD
2,4-Dimethylphenol	Extractable/A	—	8.25	8.04	FID,ECD
Dinitrobenzene	Extractable/BN	—	8.25	8.09	FID,ECD
4,6-Dinitro-o cresol	Extractable/A	—	8.25	8.04	FID,ECD

TABLE 4.2 (contd)

Compound	Sample Handling Class/Fraction	Non-GC Methods	Measurement Techniques		
				Conventional	
			GC/MS	GC	Detector[a]
2,4-Dinitrotoluene	Extractable/BN	—	8.25	8.09	FID,ECD
Endrin	Extractable/P	—	8.25	8.08	HSD
Ethyl ether	Volatile	—	8.24	8.01	FID
				8.02	FID
Formaldehyde	Volatile	—	8.24	8.01	FID
Formic acid	Extractable/BN	—	8.25	8.06	FID
Heptachlor	Extractable/P	—	8.25	8.06	HSD
Hexachlorobenzene	Extractable/BN	—	8.25	8.12	ECD
Hexachlorobutadiene	Extractable/BN	—	8.25	8.12	ECD
Hexachloroethane	Extractable/BN	—	8.25	8.12	ECD
Hexachlorocyclopentadiene	Extractable/BN	—	8.25	8.12	ECD
Lindane	Extractable/P	—	8.25	8.08	HSD
Maleic anhydride	Extractable/BN	—	8.25	8.06	ECD,FID
Methanol	Volatile	—	8.24	8.01	FID
Methomyl	Extractable/BN	8.32 (HPLC)	—	—	—
Methyl ethyl ketone	Volatile	—	8.25	8.01	FID
				8.02	FID
Methyl isobutyl ketone	Volatile	—	8.25	8.01	FID
				8.02	FID
Naphthalene	Extractable/BN	—	8.25	8.10	FID
Naphthoquinone	Extractable/BN	—	8.25	8.06	ECD,FID
				8.09	FID
Nitrobenzene	Extractable/BN	—	8.25	8.09	ECD,FID
4-Nitrophenol	Extractable/A	—	8.24	8.04	ECD,FID
Paraldehyde (trimer of acetaldehyde)	Volatile	—	8.24	8.01	FID
Pentachlorophenol	Extractable/A	—	8.24	8.04	ECD
Phenol	Extractable/A	—	8.25	8.04	ECD,FID
Phorate	Extractable/BN	—	—	8.22	FPD
Phosphorodithioic acid esters	Extractable/BN	—	—	8.06	ECD,FID
				8.09	ECD,FID
				8.22	FPD
Phthalic anhydride	Extractable/BN	—	8.25	8.06	ECD,FID
				8.09	ECD,FID
2-Picoline	Extractable/BN	—	8.25	8.06	ECD,FID
				8.09	ECD,FID
Pyridine	Extractable/BN	—	8.25	8.06	ECD,FID
				8.09	ECD,FID
Tetrachlorobenzene(s)	Extractable/BN	—	8.25	8.12	ECD
Tetrachloroethane(s)	Volatile	—	8.24	8.01	HSD
Tetrachloroethene	Volatile	—	8.24	8.01	HSD
Tetrachlorophenol	Extractable/A	—	8.24	8.04	ECD
Toluene	Volatile	—	8.24	8.02	PID
Toluenediamine	Extractable/BN	—	8.24		
Toluene diisocyanate(s)	Extractable/nonaqueous	—	8.25	8.06	FID
Toxaphene	Extractable/P	—	8.25	8.08	HSD

TABLE 4.2 (contd)

Compound	Sample Handling Class/Fraction	Non-GC Methods	Measurement Techniques: GC/MS	Conventional: GC	Conventional: Detector[a]
Trichloroethane	Volatile	—	8.24	8.01	HSD
Trichloroethene(s)	Volatile	—	8.24	8.01	HSD
Trichloro-fluoromethane	Volatile	—	8.24	8.01	HSD
Trichlorophenol(s)	Extractable/A	—	8.25	8.04	HSD
2,4,5-TP (Silvex)	Extractable/A	—	8.25	8.40	HSD
Trichloropropane	Volatile	—	8.24	8.01	HSD
Vinyl chloride	Volatile	—	8.24	8.01	HSD
Vinylidene chloride	Volatile	—	8.24	8.01	HSD
Xylene	Volatile	—	8.24	8.02	PID

(a) ECD = Electron capture detector; FID = Flame ionization detector; FPD = Flame photometric detector; HSD = Halide specific detector; HPLC = High pressure liquid chromotography; NSD = Nitrogen-specific detector; PID = photoionization detector.

(b) Analyze for phenanthrene and carbazole; if these are present in a ratio between 1,4:1 and 5:1, creosote should be considered present.

Note: Numbers refer to analytic procedures specified by EPA for determining whether solid waste contains a given toxic constituent for purposes of compliance with the Resource Conservation and Recovery Act (42 U.S.C. 6905, 6912(a), 6927-30, 6974).

Determine the Need for Chemical Analyses (contd)

Gas chromatography and high-performance liquid chromatography are techniques for quantitative measurement of specific organic materials. These methods are not suited to qualitative identification of unknown materials in a sample; rather, they are best used for measurement of materials known to be present. They can be relatively expensive and time consuming, but are able to analyze in the ppb (parts per billion) range. Although these methods require sophisticated equipment and highly trained operators, advances in mobile laboratories make field analysis possible. Also, portable GCs suitable for field use are now being produced.

Gas chromatography/mass spectrometry has been primarily used for qualitative analysis. Advances in equipment, however, have resulted in the use of GC/MS for quantitative measurement of pollutant levels in environmental samples. A major feature of GC/MS is the ability to simultaneously analyze, at a ppb or sub-ppb level, for a large number of organics, making it particularly suitable for use when specific contaminants are unknown. This technique is expensive and may require several days to complete. GC/MS may prove to be more cost effective than GC because a number of contaminants can be quantified at once. Mobile laboratories are also available with GC/MS capabilities.

Atomic absorption spectrophotometry and inductively coupled argon plasma spectrometry are used for quantitative determination of the concentration of heavy metals in the ppm or ppb range. AA is used for determination of concentrations of individual metals, whereas ICAP can perform several dozen metal analyses at once. Although both

Determine the Need for Chemical Analyses (contd)

methods require sophisticated equipment and trained operators, AA is the simpler and cheaper of the two. ICAP, however, may be more cost effective if several elements are being analyzed. Currently, AA is available in mobile field laboratories.

Instrumental analyses should be used when an exact quantification of contaminants is needed or when no other means exist for identifying unknown contaminants. Obviously, instrumental analyses can be used only when adequate time, funds, and a laboratory are available.

Costs and time requirements for instrumental analyses can vary significantly. A substantial economy of scale is associated with instrumental analyses because of the time and cost of the initial set-up and calibration of instruments. Costs may be lower for common analyses such as PCB because a large number of laboratories are set up for routine PCB analysis. In an emergency situation, nonroutine analyses may be required and higher costs should be expected. Average costs are reported in Table 4.1; the actual costs will vary, depending on circumstances.

Field Analytical Methods—A variety of analytical methods have been developed for use in the field for detection and identification of hazardous materials. The *Field Detection and Damage Assessmen: Manual for Oil and Hazardous Materials Spills* (EPA 1972) describes qualitative procedures and tests that may be used in the field to identify chemicals. The OHM-TADS system also identifies field detection methods and their sensitivities. The Hach Company of Loveland, Colorado, has developed a portable Hazardous Materials Detection Laboratory that can be carried into the field to test for more than 300 hazardous materials. Analytical Instrument Development, Inc., of Avondale, Pennsylvania, has a portable gas chromatograph available, suitable for field identification of approximately 400 chemicals. Portable equipment for detecting hazardous materials in the air is available from SKC, Inc., Fullerton, California. Portable vapor detectors and organic vapor analyzers can be used to rapidly determine the extent of contamination by organic materials, locate "hot spots," and design a sampling program for detailed analyses. The use of portable GCs and infrared (IR) spectrophotometers for identifying and quantifying organic vapors is described by Vanell (1982). Portable explosimeters can rapidly assess the safety of an emergency response scene. Portable gas detector tubes are available that can easily and quickly determine the concentrations of a variety of gases. These tubes are described by Verschueren (1977).

Another analytical method that may prove useful for field determination of contamination is the Microtox system recently developed by Beckman Instruments of Fullerton, California. This system provides a quick means of detecting the presence of toxic materials, and could be used as a qualitative indicator of contamination. Most of the traditional wet chemical methods described in *Standard Methods for the Analysis of Water and Wastewater* (APHA 1980) and in *Manual of Methods for the Chemical Analysis of Water and Wastes* (EPA 1976) are suitable for use in the field. Determinations to the ppm level are usually possible and analyses typically cost only a few dollars each. Unfortunately, these methods are usually not available for analysis of toxic and hazardous constituents. A recent advance in these procedures, especially for field

Determine the Need for Chemical Analyses (contd)

application, is the use of ion-specific electrodes. Also, a variety of spectrophotometric methods are available for quantitative determination of a number of inorganic pollutants. The above-mentioned Hach Company analyses cost only a few dollars each to perform, and can be performed by persons with limited training. Determinations to the ppm and sub-ppm levels are usually possible.

Which field analytical method is chosen depends on the emergency situation. If the hazardous material is in an easily accessible location gas chromatography and infrared spectrophotometers may be appropriate. This equipment requires a skilled operator. An unskilled operator, who has not had proper preparatory training, could obtain faulty results. The operator of any equipment must be familiar with that equipment. If the proper commitment to gaining this familiarity cannot be made, contracting the field analytic work should be considered. If skilled operators are not available or the material is not in an accessible location, the Hach company's portable detection laboratory could be approriate.

In general, field methods should be used at emergencies because of their lower costs, rapid turn-around time, and availability of equipment. However, if quantitative determinations of low levels of contaminants are needed, these methods will probably not suffice.

Preparing for Emergencies—For chemical analyses to be useful in emergency response, scientific support staff must be familiar with the capabilities and limitations of each method; thus, they can offer advice on selection of methods during a response. Information should be kept on file describing the analytical methods available, the materials that each can analyze for, as well as their detection limits. Appropriate analytical methods and detection limits for a number of chemicals, especially gases, are identified by Verschueren (1977).

Laboratories should be identified where instrumental analyses can be performed. *The Hazardous Waste Services Directory* (1980) lists hazardous materials laboratories on a state-by-state, city-by-city basis and includes descriptions of the analyses they can perform. Also, EPA regional staff or state environmental regulatory agencies may have available lists of laboratories that are equipped and certified for hazardous materials analysis. A laboratory with a mobile unit that could bring instrumental capabilities to the field is preferable. The EPA Oil and Hazardous Materials Spills Branch in Edison, New Jersey, has developed such a mobile unit (Environmental Emergency Response Unit Mobile Laboratory), which may be available for use. The laboratory(s) selected should be requested to provide estimates of analytical costs and turnaround times for various emergency scenarios that may be encountered.

If the laboratory has mobile facilities, estimates of mobilization times and costs should be obtained. The laboratory(s) should agree to provide around-the-clock work if necessary. Copies of the laboratories' Quality Assurance (QA) procedures should be obtained, and reviewed and approved by EPA QA staff. The laboratories' analytical procedures must be those approved by EPA (44 *Federal Register*, 69464-69575, Monday, 3 December 1979). Requirements of the laboratory(s) concerning how samples must be packed, shipped, and preserved must be

obtained. A large supply of approved sample containers (see above *Federal Register* reference), shipping containers, and packing material should be assembled and kept ready for immediate use. As it is possible that some samples may be considered hazardous substances, DOT regulations should be reviewed to identify those that may affect shipment of samples. Provisions must be made to assure a proper chain of custody.

Necessary field analytical equipment should be assembled and kept ready for use. Scientific support staff should be familiar with the operation of field analytical equipment and sampling procedures. Procedures for sampling wastes and water are given in *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods* (EPA 1980) and in ASTM (1982, Method D-3370). Verschueren (1977) identifies and provides references for methods of sampling many airborne contaminants. Even though scientific support personnel probably will not be involved directly with field sampling and analysis, their knowledge of procedures will help to identify and correct improper techniques. For example, in the confusion of an emergency response, a contractor may be collecting samples for organic analysis in polyethylene jars instead of in amber glass jars. Being able to spot this error could assure the quality of data that may later be used in legal proceedings.

Determine the Reactivity of Chemicals

Major data sources for determining the reactivity of chemicals are data bases and published handbooks. The OHM-TADS data base maintained by EPA provides rapid access to information on reactivity of over 850 chemicals. This includes identification of binary reactants, corrosiveness, recommended containers, flammability, explosiveness, and additional chemical hazards. The CHRIS Manual CG-446-2 (USCG 1974b) contains extensive reactivity data on approximately 900 chemicals. Data include information on reactivity with water, reactivity with common materials (including containers), stability during transport, neutralizing agents, polymerization reactions and inhibitors, requirements for inert atmospheres, flammability,and flash points. *The Manual of Hazardous Chemical Reactions,* NFPA 491M, published by the National Fire Protection Association, Boston, Massachusetts, contains descriptions of over 3500 hazardous chemical reactions, identified by reactant. References for each reaction are also provided. A hazardous waste compatibility manual prepared by Hatayama et al. (1980) includes a reference chart, grouping common hazardous materials into 41 classifications. All possible binary reactions identified as heat generation, toxic gas generation, fire, innocuous and nonflammable gas generation, flammable gas generation, explosion, violent polymerization, solubilization of toxic substances, and unknown but potentially hazardous reactions between any of the 41 groups are identified. Sax (1979) identifies chemical incompatibility of over 1000 different materials.

If information concerning reactivity of a particular substance cannot be found through the above sources, the best alternative is the use of a consultant. Contacts within the chemical industry, universities, or research laboratories would probably be able to predict reactivities of substances lacking data, based on the properties of similar substances having data.

Preparing for Emergencies—Scientific support personnel should have the necessary data sources on hand to be able to provide rapid determination of potential chemical reactivity problems at the scene of

Determine the Reactivity of Chemicals (contd)

an emergency. Staff should obtain the reference handbooks described above and keep them ready for use. Provisions should also be made for use of the OHM-TADS system and contacts should be made with expert consultants who can be contacted on short notice to obtain needed data.

Predict the Behavior of Contaminants in the Environment

Once released to the environment, chemicals can undergo a number of physical and chemical transformations, the most important of which are volatilization, degradation, sorption to soil or sediments, and bioaccumulation. Knowing the chemical/physical properties of contaminants is useful in predicting these transformations and the behavior of contaminants both during and after the emergency. Specific chemical pathways and the chemical/physical properties that affect these are summarized in Table 4.3 and are discussed below. Sources of chemical/physical data are discussed on pages 4.19-22.

Volatilization—Volatilization is a mode by which organic chemicals may disperse through the environment. Chemical volatilization rates

TABLE 4.3. Chemical/Physical Properties Useful in Describing Environmental Behavior of Chemicals

Environmental Pathway	Chemical/Physical Property
Volatilization	Vapor Pressure
	Molecular Diffusivity
	Solubility
	Henry's Law Constant
	Boiling Point
	Molecular Weight
Biological Degradation	Biodegradation Rate Constant
	Biochemical Oxygen Demand (BOD)
Hydrolysis	Hydrolysis Rate Constant
	Reaction with Water
Photolysis	Photolysis Rate Constant
	Reaction with Water
	Reaction with Air
Chemical Oxidation	Reaction with Air
	Reaction with Water
Sorption	Distribution Coefficient, Kd
	Organic Carbon Distribution Coefficient, K_{OC}
	Octanol/Water Partition Coefficient, K_{OW}
Bioaccumulation	Bioconcentration Factor
	Octanol/Water Partition Coefficient, K_{OW}

Predict the Behavior of Contaminants in the Environment (contd)

depend largely on the vapor pressure of the chemical. Direct evaporation rates of chemicals from surface spills, floating slicks, or landfills may be calculated using vapor pressure and molecular diffusivity in air (Thibodeaux 1981; Shen 1981). Volatilization rates of dissolved chemicals may be calculated similarly using solubility data and Henry's Law constants. Smith et al. (1977) and Neeley (1980) discuss methods for predicting the volatilization rates of dissolved chemicals from natural water bodies using solubility and vapor pressure data and molecular weight. If insufficient time or data are available to calculate evaporation rates, vapor pressure is a good general indicator of volatility (or vapor pressure and solubility in the case of dissolved chemicals). Siewert (1972) presents a correlation between boiling points and evaporation rates for estimating evaporation rates of pooled liquids.

Degradation—Common chemical degradation mechanisms are hydrolysis, photolysis, biodegradation, and chemical oxidation. The easiest method of predicting degradation rates is to use measured rate constants. If these are unavailable, the degradation rates can be calculated based on chemical/physical data (Lassiter, Baughman and Burns 1978), although in emergency situations this is rarely practical. Qualitative or semiquantitative indicators of degradation rates may be more useful. For example, biochemical oxygen demand (BOD) is a good indicator of the relative biodegradability of organic chemicals in water. More useful still is the ratio of BOD to chemical oxygen demand (COD). The BOD/COD ratio can range from 0 to 1. The higher the value of BOD/COD, the more biodegradable the material. General descriptions of water and air chemistry will give an indication of whether a chemical should be expected to hydrolyze or photodegrade, and how rapidly this should occur.

Sorption—The amount of chemical that will sorb to soil or sediments is most easily calculated using sorption coefficients. In many cases, however, these are unavailable. Octanol/water partition coefficients also provide a means of estimating the tendency of a chemical to bind to the soil and thus to resist leaching. The sorption coefficients of organic chemicals to soil can be estimated from the chemicals' octanol/water partition coefficient (K_{OW}) using relationships developed by Karichhoff et al. and Briggs, presented by Neeley (1980). The lower the value of octanol/water partition coefficient, the greater the tendency to leach. Values of K_{OW} for organic chemicals typically range from about 0.5 to 10^6. In general, materials having a K_{OW} greater than 100 should not move rapidly through the soil. Sorption of inorganic chemicals to soil can be qualitatively estimated from the speciation of the chemical (e.g., doubly charged cations are strongly sorbed to clay soils, singly charged cations are less strongly sorbed, and anions are generally not sorbed well). Data on soil properties affecting sorption (percent organic carbon, ion exchange capacity) can be obtained from local USDA Soil Conservation Service offices.

Bioaccumulation—Biological uptake and accumulation are important considerations in evaluating the fate of environmental contaminants. Unfortunately, relatively few specific data may be available describing the bioconcentration of chemicals. Methods are available, however, to estimate bioconcentration factors from octanol/water partition coefficients (Veith, Defoe and Bergstedt 1979; Branson, Neeley and Blau 1975).

Identify Chemical/ Physical Property Data Sources

A variety of sources of chemical/physical property data are available. Handbooks, data bases, and consultants are the best sources for use in emergencies. Other possible sources are scientific literature and analyses. A summary of specific handbooks and data bases, and the chemical/physical data they contain, is given in Table 4.4.

Handbooks—Handbooks are an excellent source of chemical/physical data on individual chemicals, and can be used in the field. A

TABLE 4.4 Summary of Chemical/Physical Data Available from Handbook and Data Bases

	Handbook or Data Base						
	Chris Manual CG446-1,2 (USCG 1974a and 1974b)	EPA Field Detection Manual (1972)	Verschueren (1977)	Sax (1979)	Dawson, English and Petty (1980)	Merck Index (1968)	OHM-TADS
Chemical Synonyms	x	x	x	x	x	x	x
Molecular Weight	x		x	x	x	x	
Solubility in Water	x		x		x	x	x
Vapor Pressure	x		x	x	x		x
Boiling Point	x	x	x	x		x	x
Melting Point	x		x	x		x	x
Liquid Specific Gravity	x		x	x	x	x	x
Vapor Specific Gravity	x		x	x	x		
Saturated Vapor Concentration			x				
Henry's Law Coefficients(a)							
Observable Characteristics	x	x	x	x		x	x
Odor Threshold	x		x		x		x
Sampling and Analysis Methods		x	x				x
Chemical Reactivity	x						x
Reactions in Water	x	x	x		x		
Reactions in Air			x				
Biodegradation Rate Constant			x		x		
BOD	x		x		x		x
Hydrolysis Rate Constant					x		
Photolysis Rate Constant					x		
Bioconcentration Factor			x		x		
K_{ow}					x		
K_d					x		
K_{oc}					x		
Number of Chemicals	900	329	>1,000	13,000	250	10,000	850

(a) A collection of Henry's Law coefficients is not readily available, but is being prepared for another manual in this series. Table 4.4 will be revised when the above-mentioned manual is completed

Identify Chemical/ Physical Property Data Sources (contd)

limitation is that data are often reported for only one set of conditions (e.g., for 25°C and 1 atmosphere). Some properties can change markedly with temperature, and reported values may not represent conditions at a response scene.

CHRIS, the Coast Guard Hazardous Chemical Data Manuals CG 446-1 and *CG 446-2*, are excellent sources of data on approximately 900 hazardous materials. The data contained in these and other CHRIS manuals are designed for use with the Coast Guard's Hazard Assessment Computer System (HACS), a computerized simulation system that models the physical behavior of chemical spills and provides information describing the extent of the hazard associated with these spills (Parnarouskis, Flessner and Potts 1980).

The EPA Field Detection and Damage Assessment Manual for Oil and Hazardous Materials Spills (EPA 1972) is useful for supplying data needed for identifying any of 329 hazardous materials in the field.

The Handbook of Environmental Data on Organic Chemicals (Verschueren 1977) is an excellent source of data describing the behavior of over 1000 organic chemicals in the environment. This is perhaps the most complete collection of environmental chemical data that can be easily taken into the field.

Dangerous Properties of Industrial Materials (Sax 1979) is a collection of physical, chemical, and toxicological data on almost 13,000 common industrial and laboratory materials. The data deal primarily with the hazards posed by the materials and include acute and chronic toxic hazard ratings, toxicity figures, a description of toxicology, treatment of poisoning, and storage, handling, and shipping guidelines.

Physical Chemical Properties of Hazardous Waste Constituents (Dawson, English and Petty 1980) is a collection of data on 250 chemicals commonly found in hazardous waste streams. This collection is an excellent reference for predicting the behavior of chemicals following spills. For each chemical, quantitative estimates are included of the relative human health hazard posed by its release to the environment.

The Merck Index (1968) contains general chemical data on almost 10,000 chemical substances. This work contains descriptions of the preparation and chemistry of the various substances, with citations to the original publications in the field.

The Properties of Gases and Liquids (Reid, Prausnitz and Sherwood 1977), explains how to make estimates of various chemical and thermodynamic properties of gas and liquid mixtures. Familiarity with the principles explained in this reference is needed to use it efficiently in an emergency.

Data Bases—Several data bases contain information or chemical/ physical properties useful for emergency response. Several of these are discussed below.

OHM-TADS - The Oil and Hazardous Materials-Technical Assistance Data System contains chemical, physical, and biological data on over 850 hazardous chemicals and industrial materials. OHM-TADS contains data describing physical/chemical properties, toxicity, environmental fate and persistence, and emergency response methods. These

Identify Chemical/ Physical Property Data Sources (contd)

data are maintained on computer by EPA and are accessible by remote terminal or by microfiche.

Octanol/Water Partition Coefficient Data Base, a data base containing octanol/water partition coefficients for several thousand chemicals, is maintained by Dr. Corlan Harsch at Pomona College, Pomona, California. This is perhaps the most complete source of K_{ow} values currently available. The material in this data base can be purchased in hard copy form or on microfiche.

The Chemical Substances Information Network (CSIN) is a computerized data collection system currently being developed by EPA. Sources for this system will initially include the National Library of Medicine, the Chemical Information System, EPA's Chemicals in Commerce Information System, Bibliographical Retrieval Services, System Development Corporation, and Lockheed's Dialogue System.

Consultants—Consultants should be useful for rapidly obtaining chemical/physical data that are not available elsewhere. If the identity of a chemical is known, experts in the industry producing that chemical should be useful in providing needed data. Consultants should also be extremely valuable in estimating the properties of chemical mixtures. The chemical industry, chemistry and chemical engineering departments of universities, and technical assistance teams (TAT) and regional response teams (RRT) would all be good references.

Scientific Literature—The scientific literature should be reviewed to obtain chemical data only if such data are not available elsewhere. Several computerized search systems can aid in the rapid retrieval of chemical data from technical literature. The most efficient means of searching these systems for data on a particular chemical is to identify citations indexed to substance-specific search terms such as Chemical Abstracts Service (CAS) nomenclature or CAS registry numbers. Computerized literature files that might prove valuable include:

- National Technical Information Service—NTIS
- Institute for Scientific Information—SCISEARCH
- Data Courier, Inc.—Pollution Abstracts
- Engineering Index, Inc.—COMPENDEX
- Chemical Abstracts Service—CHEMICAL ABSTRACTS
- National Library of Medicine—TOXLINE
- Smithsonian Science Information Exchange—SSIE
- Environment Information Center, Inc.—ENVIROLINE
- Xerox University Microfilms, Inc.—Comprehensive Dissertation Index
- Defense Technical Information Center—DTIC
- Interactive Sciences Corporation—Chemical Information System.

Analyses—Chemical/physical properties of chemicals and chemical mixtures can be analytically determined, although a certain time period is necessary to obtain results. Testing laboratories capable of performing standard analyses are available in most larger cities and can be located

Identify Chemical/ Physical Property Data Sources (contd)

in the yellow pages under Laboratories-Testing. Detailed procedures for the various tests are available from the American Society for Testing Materials in Philadelphia, Pennsylvania.

Preparing for Emergencies—Several steps should be taken to assure that chemical/physical data on contaminants can be obtained quickly during an emergency response. The handbooks described above should be obtained and staff made familiar with their use and the information contained in them. These references should be kept ready to take into the field if necessary. Scientific support staff should make arrangements for access to the OHM-TADS system as described on pages 4.7-8. Because of the utility of octanol/water partition coefficients in describing the fate of contaminants, it may be desirable to obtain these data. Also, contacts should be made with consultants who can provide data on chemical/physical properties. Phone numbers of contacts should be kept ready for immediate use. Arrangements should be made for rapid access to literature search data bases and for rapid retrieval of technical literature. For example, a contact could be made at a university library who could obtain needed data and telex it to scientific support staff. Testing laboratories should be located that could determine chemical/physical properties of materials, if needed. Information from the labs should be obtained, as described on pages 4.15-16 and kept on file.

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4.2 HYDROLOGIC AND METEOROLOGIC ASSESSMENT CHECKLISTS

AIR CONTAMINATION

ACTIVITIES BEFORE OR BETWEEN RESPONSES **(see p. 4.33)**

1. Make necessary arrangements for fast acquisition of meteorological data from local sources.
2. Provide for quick turnaround plume modeling capabilities:
   - in field estimates
   - through computer models.

ACTIVITIES DURING RESPONSE **(see p. 4.33)**

1. Observe initial plume characteristics over release duration:
   - direction and speed of movement
   - puff or continuous release
   - amount or rate of material release
   - temperature
   - vertical velocity
   - height above ground.
2. Identify the nature of the contaminant:
   - liquid, gaseous, and/or particulate airborne material
   - chemical makeup
   - density
   - toxicity.
3. Identify ambient weather conditions:
   - wind speed and direction
   - upper winds direction (cloud movement)
   - variability of wind speed and direction
   - trends in current weather conditions
   - visible plume or nearby plumes
     - plume rise
     - rate of growth
     - travel direction
   - weather forecast
   - sky information
     - fraction sky cover
     - type of clouds
     - solar radiation
     - net radiation during nighttime
   - local topography
   - buildings.
4. Compute past, current, and future:
   - ground-level air concentration patterns
   - surface deposition patterns.
5. Evaluate continuing potential for hazardous downwind plume interactions.

SURFACE CONTAMINATION

ACTIVITIES BEFORE OR BETWEEN SPILLS (see pp. 4.34-35)

1. Gather existing data:
   - topographical maps
   - photos
   - climatological data availability
   - streamflow records
   - soil types
   - land use.

ACTIVITIES FOLLOWING RESPONSE (see pp. 4.35-36)

1. Identify spilled material (Does it become soluble in water, attached to sediment, or suspended in water?)
2. Identify pathways:
   - note the drainage pattern—topographic maps and aerial photos
   - interaction with ground water
   - sewer and water systems
   - soil properties affecting infiltration
   - drainage slope, channel shapes, friction of land
   - depression storage that must be filled, dams.
3. Obtain climatological data (see p. 4.34):
   - antecedent soil moisture and rainfall expected, flooding.
4. Sample downgradient or downstream surface waters, sewage outlets, storm sewer outlets (see p. 4.35).

UNDERGROUND CONTAMINATION

ACTIVITIES BEFORE OR BETWEEN RESPONSES

1. Collect existing information:
   - geologic data (see Table 4.5)
   - hydrologic data (see Table 4.6).

ACTIVITIES DURING RESPONSE

1. Collect on-scene data:
   - sample existing wells, soil (see pp. 4.42-43)
   - measure depth to ground water (see pp. 4.42-43)

4.2 HYDROLOGIC AND METEOROLOGIC ASSESSMENT

An understanding of transport and mixing mechanisms is necessary to a valid assessment of the pathways of released materials. In the event of releases from existing waste disposal sites or from a container of hazardous waste in storage or transit, estimates must be made of:

- where the material goes
- how fast it moves
- locations of impact
- environmental concentrations.

The probable pathways of the contaminant must be identified and the conditions affecting its movement must be evaluated. The pathway can be identified as one or more of the following: air, soil, surface water, or ground water. Atmospheric contaminant transport and dispersion are affected by both the release characteristics and the ambient weather conditions. Surface contamination is controlled by soil sorption and infiltration properties, deep percolation properties, precipitation, and surface-water flow patterns. A release that occurs underground, or through the soil from the surface, is affected by soil infiltration and attenuation properties, geologic formations, aquifer properties, and ground-water flow and direction. The hydrologic cycle, shown in Figure 4.1, shows possible pathways.

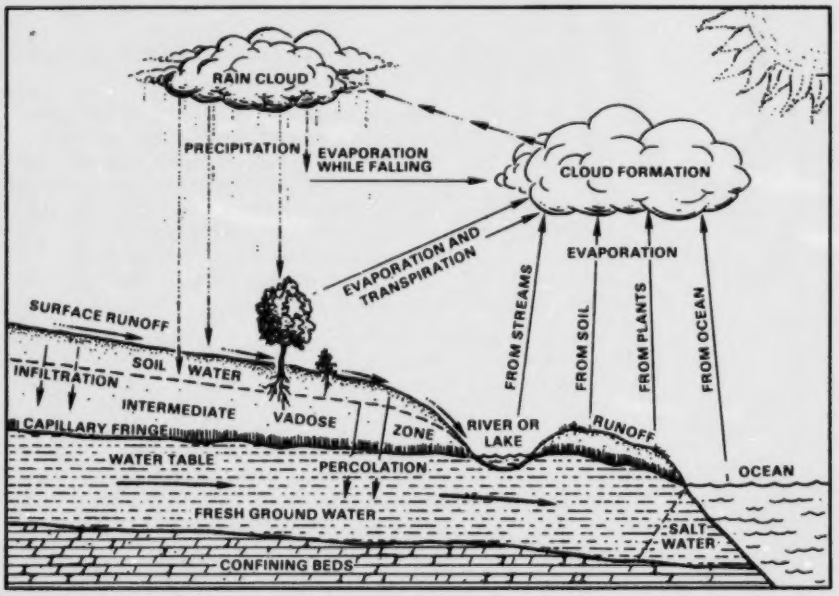

FIGURE 4.1. Schematic Diagram of the Earth's Water Cycle—the Hydrologic Cycle (from Johnson Division 1975)

AIR CONTAMINATION

Airborne contaminants can result from fires, explosions, or the release of a hazardous gas. In such events the following background information is needed:

- How will weather affect contaminant travel?
- How quickly can the wind transport the contaminant?
- How will the concentration change?
- What will happen if it rains?
- What is the expected weather in the near future?
- How do weather, buildings, and topography affect dispersion?

Concepts to be Understood Before an Incident

In addition to familiar atmospheric terms (wind speed, wind direction, temperature), several special terms are important:

Stability—a measure of the ambient mixing rate of the atmosphere. Very stable conditions have slow dilution rates typical of nighttime conditions; unstable conditions have fast dilution rates typical of daytime conditions. Intermediate mixing conditions are called neutral stability. A number of approximately equivalent methods summarize stability classes as indexes or letter classifications. These are used to classify stability for atmospheric dispersion modeling.

Plume rise—the height of rise of a plume of released material.

Source term—the amount (or rate) of material released to the atmosphere.

Release height—the height over local grade that the release occurs.

Exit velocity—the initial upward velocity of the release.

The information required for analysis will be determined by the nature of the hazardous material released. In the case of particulates, accumulated deposition is often the most important exposure mechanism. Gaseous plumes tend to present short-period exposure problems. Very small particles will behave like vapors; large particles in a plume will fall below the vapor plume, resulting in higher ground-level concentrations and deposition rates closer to the release location. Figures 4.2 and 4.3 illustrate the concentration and deposition patterns for releases with and without plume rise.

As an airborne contaminant is released, it immediately begins mixing with the surrounding atmosphere. Progressive dilution occurs as the contaminant moves downwind. Average contaminant concentration may be visualized, as shown in Figures 4.2 and 4.3, as having a peak along the centerline or axis of the plume and decreasing with distance traveled. This representation is a time average of actual plumes, which individually will vary. Also, the rate of downwind plume growth will vary with ambient conditions.

The plume centerline or line of maximum concentration is not always at ground level. The elevation of the plume centerline is determined by various factors:

- release characteristics
- ambient atmospheric conditions.

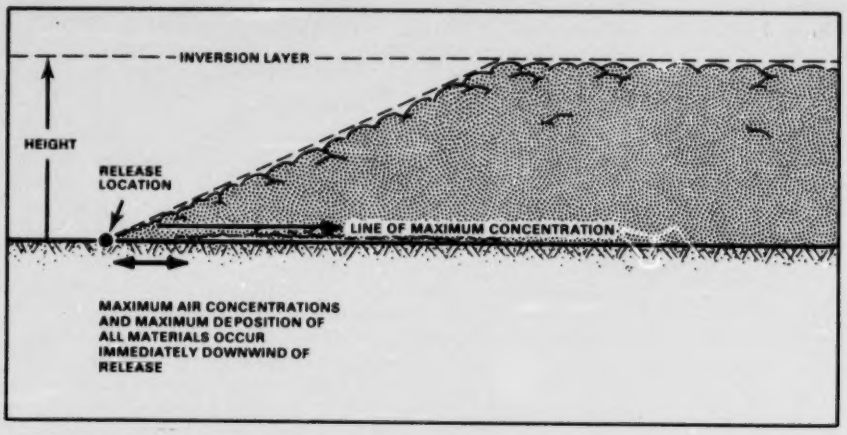
INVERSION LAYER
HEIGHT
RELEASE LOCATION
LINE OF MAXIMUM CONCENTRATION
MAXIMUM AIR CONCENTRATIONS AND MAXIMUM DEPOSITION OF ALL MATERIALS OCCUR IMMEDIATELY DOWNWIND OF RELEASE

FIGURE 4.2. Illustration of Air Concentration and Deposition Distributions for a Release Without Plume Rise

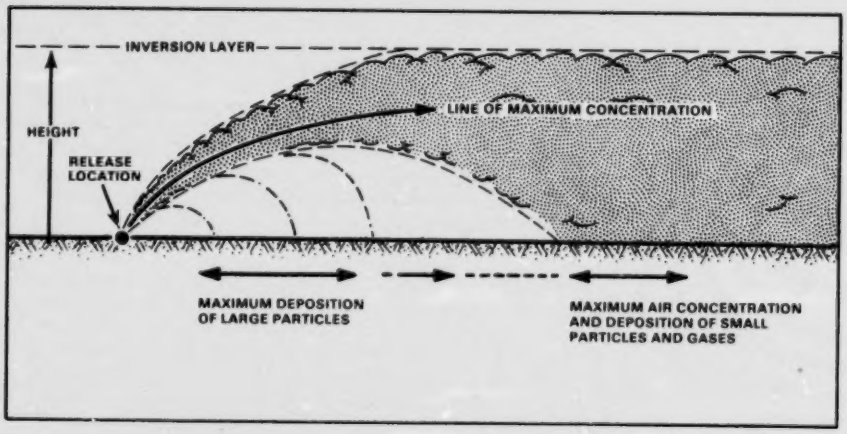
INVERSION LAYER
HEIGHT
RELEASE LOCATION
LINE OF MAXIMUM CONCENTRATION
MAXIMUM DEPOSITION OF LARGE PARTICLES
MAXIMUM AIR CONCENTRATION AND DEPOSITION OF SMALL PARTICLES AND GASES

FIGURE 4.3. Illustration of Air Concentration and Deposition Distributions for a Release With Plume Rise

Concepts to be Understood Before an Incident (contd)

Release characteristics consist mainly of any upward or ejection speed and the relative densities of the material and the ambient atmosphere. Principal atmospheric factors are wind speed and stability. An atmospheric inversion layer may limit the vertical dispersion (see Figures 4.2 and 4.3)

The highest ground-level concentrations result from releases at ground level with no plume rise. However, releases with plume rise can result in high ground-level concentrations if: 1) the plume dispersion reaches ground level or 2) the plume centerline intersects topography or buildings. These occurrences can be caused or intensified by atmospheric inversions.

Low-density plumes rise as a result of buoyancy alone; high density plumes fall. Under low wind speed conditions, low-density vapor plumes tend to rise, leaving the ground free of contamination in the neighborhood of the plume source. High-density vapor plumes, and the larger size particulate content of all plumes will fall to the ground in the vicinity of the release. The path of high-density plumes will tend to follow local topography in a manner quite similar to surface liquid releases, particularly for the low-wind-speed, stable atmospheric conditions.

Increasing wind speeds and decreasing stability tend to reduce plume rise. At high wind speeds, most releases will act like passive ground-level releases. The more unstable the atmosphere, the sooner the released material will lose its initial buoyancy difference through mixing with air. Although the enhanced dispersion will reduce the plume centerline concentrations, the reduced plume rise can result in much higher ground-level concentrations.

Although dispersion and buoyancy usually control the movement of a release in the atmosphere, other physical and chemical processes may be important. Precipitation may wash out material to ground level or only lower the atmospheric plume. The effect depends on the capture or solubility properties of the released material. Chemical and phase changes may affect the concentration, and other plume properties, of materials.

A description of atmospheric motion must include a detailed specification of wind velocity, both temporal and spatial. Velocity may be conveniently divided into its time-averaged direction and speed, and into its fluctuating components, termed turbulence. The division is somewhat arbitrary. Most dispersion models require an average of 10 to 60 minutes duration to match the averaging time of dispersion coefficients. The exceptions are instantaneous puff models, which use release-time values.

The vertical and horizontal concentration distribution of a plume depends on the vertical structure of the atmosphere. Interaction of stable layers (inversions) with the plume can control the geometric shape and dispersion of the plume.

Topography, building, and other obstructions affect local air motions, perhaps altering the plume path, elevation, and diffusion. The influence of an obstruction extends upward a distance about the height

Concepts to be Understood Before an Incident (contd)

of the obstruction. Turbulence, as well as wind speed and direction, is affected. For abrupt obstructions, the generation of turbulence is the striking feature.

The effect of topography is uncertain. For example, a plume on the windward side of a hill may follow the air stream up the side, as shown in Figure 4.4, with the usual dispersion about its now-distorted axis. The plume might also travel partly, or totally around the hill, depending on atmospheric stability, structure, and hill geometry. Division of the plume into several parts is possible. Assuming the plume goes over the hill, the processes on the leeward side can be quite different. If a turbulent wake region exists, a plume may be brought quickly to the ground, as shown, and be diffused over a wide area. In an extreme case, the plume may move back up the hill.

The general effect of complex terrain is to increase the amount and speed of dispersion. The exception is for dense plumes caught in a drainage flow contained by topography. Also, in complex terrain, greater variations in ground-level concentrations are probable (through plume and ground intersections and plume fragmentation). These possible plume effects will have to be taken into consideration.

Required Data

To define the atmospheric path and dispersion of the release, certain characteristics of the release and atmospheric conditions must be determined. The following describes the specific data required, why the data are required, and how to obtain them.

The best estimates of release conditions are needed to define plume rise and initial dilution. The first step is to define the way in which the contaminant is injected into the atmosphere.

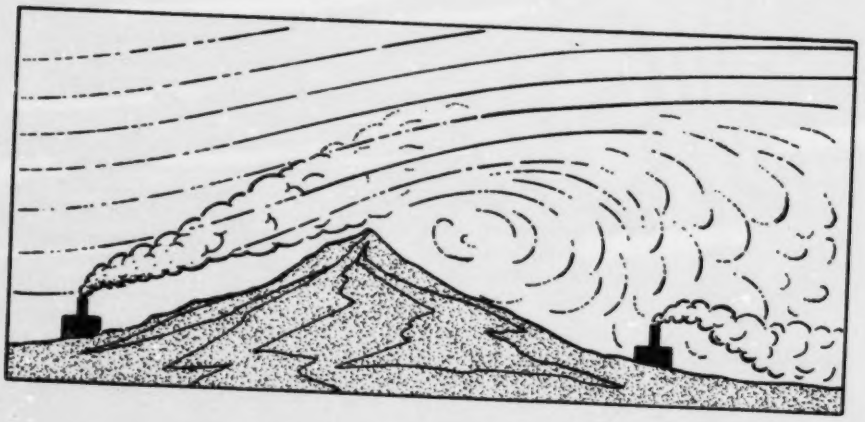

FIGURE 4.4. Pattern of Air Motion Over a Hill, Showing Effect on Vapor Plumes (after Stern 1968)

Required Data (contd)

The translation of the onsite data to estimates of ground-level concentrations will be required in order to assess potentially hazardous areas. Is the release a puff or a continuous release? Important parameters are rate, temperature, density, vertical velocity, and size of the contaminant release. For example, a cold, dense, vapor release will tend to travel along the ground, but a plume from a fire may rise to considerable height. The second step is to define the ambient meteorological conditions and factors at the release point. Important parameters are wind speed, atmospheric stability, and local dispersion influences.

Hazard assessment will also require knowledge of wind speed, wind direction, and stability for the time of release, and for the anticipated duration of the plume. The definition of stability will depend on the model selected for computations.

To obtain the necessary atmospheric data, data concerning past and current conditions, as well as predictions of future conditions, are needed. Although the winds at the time of an accident may be away from a local population center, a shift in winds may send the plume in any direction. In areas with complex topographic influences on local air circulations, the spatial variations in wind-flow patterns must be known in order to assess potential trajectories of atmospheric contaminants. This refers to areas adjacent to oceans and lakes (land-sea breeze effects) and mountainous/hilly areas.

Plume-dispersion models can be of use in the field as well as for between-incident study. Programs are available from the companies that manufacture hand-held programmable calculators, or from individuals who have developed their own models. Calculator companies solicit programs from users; therefore, a wide variety of models may exist that are not available through the companies.

Simple Gaussian models proposed by Pasquill, Turner, or Gifford (see references) provide a means of making quick concentration estimates as a function of downwind distances. Because these are applicable only to ideal conditions without complex local influences, they should be used only as guides for the order of magnitude of potential concentrations.

Except at well-exposed sites, the onsite observations of meteorological data will be applicable only for near-site estimates of transport and dispersion. Extrapolation of local wind direction/speed observations for downwind trajectories should be performed with great caution. Observations from a poorly exposed wake of a hill or building may not accurately assess the airflow over the area that defines the downwind direction of transport.

When obtaining characterization of atmospheric transport and dilution, knowledge of the range of possible conditions is more useful than a single "most likely" condition. For example, factoring in a range of possible arrivals of weather systems is a superior approach to assuming a single arrival estimate.

Predictions of atmospheric conditions should be made specifically for the release area, by someone who is familiar with both synoptic and regional weather influences for the area where the release occurred.

Required Data (contd)

A mini-computer-based system will be appropriate for emergency preparedness computation of potential atmospheric pathways. Such a system should use region-specific models and inputs.

On-Scene Activities

Data should be noted in terms of the following divisions:

Release substance—What is the:
- chemical form?
- physical form?
- total amount in accident?
- amount potentially released?

Release Characteristics—What is the:
- release rate?
- height above ground?
- temperature?
- vertical velocity?
- horizontal velocity?

Plume Dispersion for Visible Plumes—What is the:
- plume rise?
- plume rate of growth?
- direction of travel?

Local Dispersion Influences—Are there:
- building wake effects (distance to buildings; height of close buildings)?
- upwind surface roughness effects (urban or rural)?
- topographic influences?

Ambient Meteorological Conditions—What is the:
- surface-wind direction and speed at release?
- surface-wind direction and speed at an adjacent well-exposed site?
- direction of elevated winds (cloud movement)?

Sources of Existing Data

Listed below are typical sources for meteorological data. Twenty-four-hour phone lists, interagency agreements for data, and other logistics should be prepared as part of emergency planning for fast acquisition of data. The National Climatic Center run by the National Oceanic and Atmospheric Administration in Asheville, North Carolina, can provide information on the types of weather data available in a particular area.

- First Order Weather Stations—usually found at airports
- Nuclear Power Plants—control room
- University Stations
- Forestry Stations
- Department of Agriculture Stations
- TV/Radio Monitors
- Government Monitoring Installations
- Government Nuclear Installations
- Local Authorities for Air Pollution Control

The specific agencies available for contact depend on the local region.

SURFACE CONTAMINATION

Many emergency situations involving hazardous materials begin with a surface spill. A surface spill can occur during the transportation or storage of hazardous materials, on or near the surface. A spill of any sort can rapidly become an emergency situation because of the proximity of human activity and because of the relatively brief travel times associated with surface flow. These brief travel times require very fast response to any emergency situation to minimize the severity of potential damages. In an emergency situation the response team must:

1. obtain existing data
2. obtain on-scene data
3. evaluate contaminant transport.

Obtain Existing Data

Site-specific data are required for the evaluation of factors that influence the pathway of a surface spill. Existing data include topographic maps, aerial photography, climatological data, streamflow records, soil survey maps, and land-use classification maps.

The smallest scale, smallest contour interval (highest resolution) topographic maps available should be used. These are usually USGS 7-1/2' Topographic Maps. These maps are useful in defining drainage patterns and the presence of human populations. Maps can be purchased at sporting goods or map stores, or ordered from the USGS. To order maps of areas west of the Mississippi River (as well as Alaska, Hawaii, Lousiana, Guam, and Samoa), write to the Branch of Distribution, U.S. Geological Survey, Box 25286k Federal Center, Denver, Colorado 80225. Maps of areas east of the Mississippi River (as well as Minnesota, Puerto Rico, and the Virgin Islands) should be ordered from the Branch of Distribution, U.S. Geological Survey, 1200 S. Eads St., Arlington, Virginia 22202.

Aerial photography is useful for the same reasons as topographic maps. Small-scale stereo pairs can be used to define drainage between countour intervals. If existing photography is too old or indistinct to be useful, photographs at a lower altitude may be necessary. To obtain aerial photographs see Appendix A, Part 3 of the *NEIC Manual for Groundwater/Subsurface Investigation at Hazardous Waste Sites* (EPA 1981; hereafter referred to as *NEIC*).

Climatological, streamflow, and soil data are needed to define rainfall-runoff processes. Useful data include hourly precipitation, daily temperature, daily solar radiation, daily evaporation, daily wind velocity, daily relative humidity, snow depths, and range of snow cover. Climatological data are published by the National Oceanic and Atmospheric Administration and are available through the National Climatic Center in Asheville, North Carolina. Permanent streamflow recording stations in the area should be identified. The location of streamflow gaging stations can be obtained through the USGS data base called Catalogue of Information on Water Data—Index to Water Data Acquisition or from the Assistance Center at each USGS Water Resources District Office (USGS 1981). Aerial photography, soil type, and land-use classification data are available through the county or district office of the Soil Conservation Service and local or regional planning boards. See Appendix A, Part 5 of *NEIC* for lists of State Conservation Offices and soil surveys published by county. Other sources of hydrologic data are state geological surveys [see Appendix A, Part 6 of *NEIC* for names and numbers].

Travel times have often been calculated by the USGS, Water Resources Division District Offices; the U. S. Army Corps of Engineers; National Oceanic and Atmospheric Administration, National Ocean Survey; and the state Waterway Commissions as a part of previous studies. These agencies are excellent sources for this type of data.

Obtain On-Scene Data

Physical and chemical characteristics of the spilled material affect contaminant transport (as discussed below—see also Chemical Characterization Section.) Data that must be gathered at the spill scene often include site-specific sampling of water and sediments, surveying stream cross-sections, measuring discharge, aerial photography, and site photography.

Both suspended and bed-load sediment must be sampled near the spill scene. Water-quality sampling should be concurrent with the sediment sampling. The water should be tested for chemicals contained in, or related to, the hazardous material. If no permanent streamflow gages are near the site, discharge will have to be measured. Photographs of the site are useful in determining friction factors and for refreshing memories after a site visit.

Evaluate Contaminant Transport

The physical and chemical characteristics of the hazardous material will determine its ultimate pathway and fate; thus, identifying the material characteristics as accurately as possible is very important. Vital characteristics include the physical state (solid, liquid, or gaseous); if particulate, the particle size; if liquid, the viscosity, density, and solubility; tendencies to form solution or colloidal suspensions; sorbtive tendencies; and any pertinent chemical tendencies. Another vital assessment is whether the spill constitutes a continuous source or a pulse source of the material.

A hazardous material on the surface can seep into the ground, be picked up into the atmosphere and possibly be redeposited, or can remain on the surface. This section deals with pathways along the surface and includes overland flow and channel flow and a combination of the two. The mode of transport along these pathways depends on the characteristics of the hazardous material.

If the surface spill is gaseous it will disperse through the atmosphere, although heavy gases may behave as liquids. If the material is liquid it will immediately begin to flow downhill. Generally, there is not enough hazardous material to maintain the flow. In this case, the material may be deposited along the pathways, to be picked up by subsequent rainfalls and associated runoff. If the material is a solid it generally will remain in place until disturbed by rainfall or wind. Small particles of solid material can be transported by wind. Rainfall can transport solid or liquid materials by way of overland flow.

Some factors that influence overland flow are precipitation; drainage patterns; slope; viscosity, density, and solubility of the material; soil types; land use; and antecedent moisture conditions. Before overland flow may begin, depression storage (the volume of fluid required to fill small depressions and pockets on the ground surface) must be filled. The amount of fluid that will infiltrate into the ground depends on ground cover, antecedent moisture, land use, and the surface-soil type. The dissolved contaminant material will infiltrate with the water and the suspended and sorbed material may be left behind.

Overland flow can be either sheet flow or rill flow. Rills and gullies gather the flow into small channels and finally into large channels, according to the prevalent drainage pattern in the area. This drainage pattern can be determined with 7-1/2' USGS Topographic Maps.

Evaluate Contaminant Transport (contd)

Factors that affect channel flow include channel geometry, channel slope, and friction. Channel flow is discussed in detail in a number of open channel hydraulics texts. In overland flow and channel flow there are three forms of material transport: a hazardous material may sorb onto the sediment carried by the flow; it may be carried as a suspended solid or as a colloidal suspension; or it may be carried as a solute. Solute transport is the fastest, approximately that of the water. If the material is carried sorbed onto sediment, sediment transport processes will dominate the transport of the material. If the material is carried as a suspension or as a solute, the properties of diffusion, dispersion, and convection will dominate its transport.

In many instances, these pathways can be either blocked or short circuited. For example, a dam, blocking the sorbed-sediment pathway by decreasing the velocities in the reservoir, will cause the sediment to settle out. A sewer can short-circuit a pathway by intercepting the flow containing the material and conveying it to another location. If the sewer in question is a storm sewer, the new location will probably be a larger channel or stream. If it is a sanitary sewer, the material may be conveyed to a central treatment location. In either case, all sewer overflow locations should be checked for the material.

The constant interaction of surface water and ground water must be considered. Rivers are normally gaining or losing water to and from aquifers. If a spill occurs in a losing reach of a river the hazardous material may contaminate the aquifer. (See the following section on underground contamination.)

Because analyses of the varied processes involved in determining the pathway and fate of hazardous material can be very complicated, computer simulation may be required. No single computer model is capable of simulating all the processes involved. The very nature of modeling makes any model an abstraction of the real world. Care must be taken to insure that the models being used make the proper abstractions for the specific sites. This is best done by an experienced modeler using a familiar code.

The general approach may be to first define the flow of water and then to define the pathway of the hazardous material within the water. The definition of the flow of water can be accomplished through simulation of the rainfall-runoff processes and of the hydrodynamics of the channel. Many models of varying degrees of sophistication are available to do this. The pathway of the hazardous material can be defined through simulation of sedimentary processes and mixing processes. Mixing can be thought of as the sum of diffusion, dispersion, and convection. Fewer models are available in these fields and the codes are much more complicated; however, the codes are available and represent the best, if not the only, way to simulate these processes.

UNDERGROUND CONTAMINATION

Underground contamination can result from surface spills of hazardous materials, seepage from deep- or shallow-well waste injec-

UNDERGROUND CONTAMINATION (contd)

tion, leaks from buried containers or leaks from underground pipelines. Surface spills that are not highly volatile or subject to overland runoff may move through unsaturated geologic material and into the ground water. (Transport by subsurface storm or sanitary sewer systems is discussed in the surface contamination section.) The upper soil layers will sorb some contaminants and the remainder may be transported deeper by infiltration or percolation mechanisms to the ground water.

Evaluation of underground contamination requires the collection of certain hydrogeologic information. One of the first steps is to locate the spill scene on a usable scale map or aerial photograph [see Appendix A of *NEIC* for obtaining these]. The map or photograph must be large enough in scale to determine the possible pathways to ground water or surface water that the spill might take. Runoff patterns and recharge zones should be defined.

The aerial view obtained by a map or photograph, as well as other data collected, should be used to create a three-dimensional image of the scene. Topographic maps can be used to draw cross-sections of the area. These data can be correlated with geologic maps to present a stratigraphic representation of the geology beneath the site. Water-level data collected from nearby wells and streams can be used to create water-table maps and piezometric surfaces.

The cross-sections and maps are used to determine the possible contaminant pathways to potable ground water or to other points of human interactions (see Figures 4.5 and 4.6). Unless the water table is at the surface, the contaminant path to ground water will be through the vadose (unsaturated) zone. This unsaturated material may attenuate or retard contaminant transport, depending on the nature of the spill and

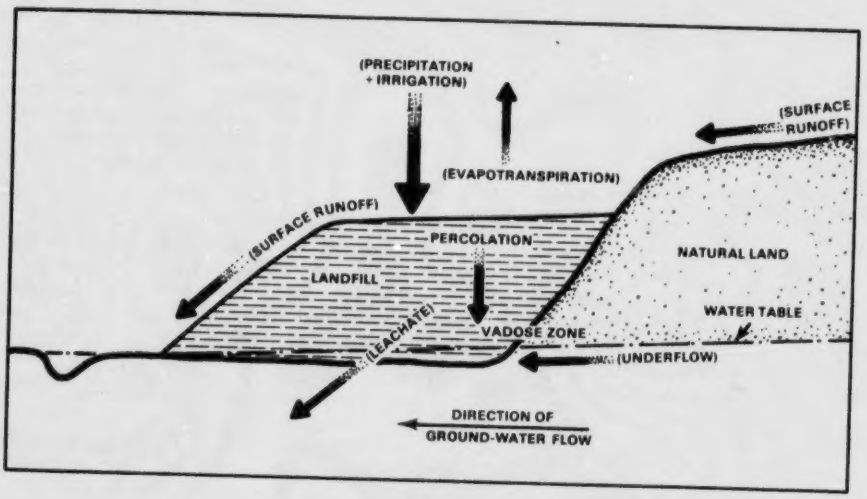

FIGURE 4.5. Simplified Landfill Water Balance (EPA 1977)

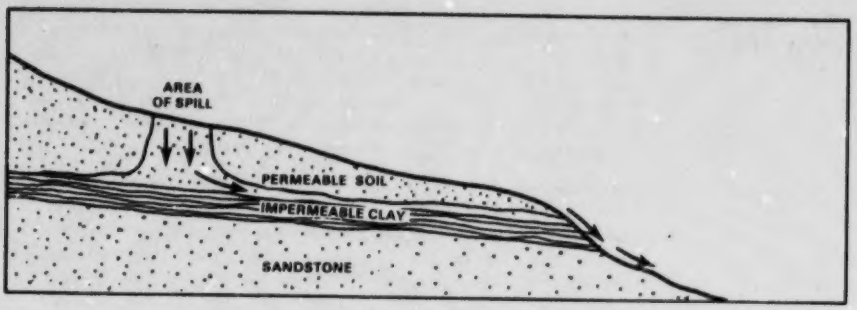

FIGURE 4.6. Vertical Cross-Section of a Hazardous Waste Site (EPA 1981)

the geologic properties of the medium. The possibility of fracture flow, which would effectively negate any retardation in the vadose zone, must be considered.

Obtain Existing Data

The initial circumstances in an emergency response are sometimes chaotic, making efficient collection of existing data difficult. Therefore, as much information as possible should be collected before spills occur. Response teams must know what they are looking for and where to find it, and must be coordinated with other emergency response groups. Relevant regional and local geologic information pertaining to consolidated and unconsolidated materials as well as other factors that affect water movement, are most important.

Geologic information that is of particular importance in site evaluation is stratigraphic section data. This information will identify the potential aquifers in the area, their relative permeabilities, and the material makeup of the area. Stratigraphic information must be examined with additional data to create a more complete picture. For example, structural information concerning fault zones, folding, structural traps, and fracture patterns is needed to help predict liquid movement. Table 4.5 is a list of types and sources of geologic information.

Site geology is often expressed in the surface topography as landforms that reflect geologic structure. The topography controls the direction of surface runoff; the subsurface structure can be the dominant control factor in ground-water movement. Figure 4.5 shows a simplified spill site cross-section with discharge to the surface.

Appendix A, Parts 2 and 6 of *NEIC* give guidance for contracting the USGS and state geological surveys. These agencies can give information on what studies have been done by public, private, and academic groups for specific areas. Local colleges and universities have libraries and faculty with information concerning studies that have been performed in the area. Local extension agents, the Soil Conservation Service, and other farm-related organizations can also be helpful.

Obtain Existing Data (contd)

Hydrologic information must be collected at the same time as geologic information to evaluate contaminant movement. Pertinent hydrologic information relates to sources of water (i.e., precipitation and ground-water flow) and down-gradient movement on the land surface or in the subsurface through permeable media. No single factor prevails at all sites; therefore, several characteristics of local hydrology must be assessed. During an investigation, all topics presented in Table 4.6 should be addressed. Again, the investigator's professional judgment will determine the extent of data gathering on a particular subject. State and Federal agencies are the best sources of information. Local water quality agencies, irrigation districts, and academic institutions should also be consulted.

TABLE 4.5. Types and Sources of Geologic Information (EPA 1981)

Topic	Definition and Sources
Stratigraphy	Stratigraphic data are formational designations, age, thickness, areal extent, composition, sequence, and correlations. Aquifers and confining formations are identified so that units most likely to transport pollutants can be delineated. Lateral changes in formations (facies change) are noted if present. Information can be obtained from the U.S. Geological Survey (USGS library, Golden, Colorado), state surveys [see Appendix A, Parts 2 and 6 of *NEIC*], and major state university libraries.
Structural Feature	Structural features include folds, faults, joints/fractures, and interconnected voids (i.e., caves and lava tubes). Deformed, inclined, or broken rock formations can control topography, surface drainage, and ground-water recharge and flow. Joints and fractures are commonly major avenues of water flow and usually occur in parallel sets. Solution features such as enlarged joints, sinkholes, and caves are common in limestone rocks and promote rapid ground-water movement. Pertinent data on structural features would include type, compass orientation, dip direction and angle, and stratigraphy. Information can be obtained from the sources listed for "Stratigraphy."
Mineral Resources and Soil Types	Mineral resources refer to commercial deposits of minerals, quarry rock, sand/gravel, oil and gas. Such deposits near the study area are identified and located. These may represent pollutant sources to be considered when planning a sampling survey. Mines and quarries can often be used for direct examination of otherwise unexposed subsurface materials. USGS topographic maps show most mines/quarries and oil fields. Aerial photographs and ground-level pictures from USGS studies can help identify and locate these features [see Appendix A, Parts 2 and 3 of *NEIC*]. County soil surveys published by the U.S. Department of Agriculture are useful because they are printed as overlays on aerial photographs. They are available through state conservation offices [see Appendix A, Part 5 of *NEIC*]. Soils information is useful in estimating infiltration of surface spills. Other published and unpublished literature is available from sources listed for "Stratigraphy."

TABLE 4.5. (contd)

Topic	Definition and Sources
Seismic Activity	In active seismic zones, disposal site covers and liners may prematurely fail because of earth movement along faults. For this reason, fault locations and the seismic history of the study area are determined. A telephone call to the state geological survey is recommended as the first step when seeking this type of information [see Appendix A, Part 6 of *NEIC* for addresses and phone numbers].
Formation Origins	Information about the origin of a deposit or formation (i.e., volcanic metamorphic, stream-laid) gives clues about structure, grain-size distribution (laterally and vertically), weathering, and permeabilities. Information can be obtained from sources listed for "Stratigraphy."
Weathering Profile	Bedrock and unconsolidated deposits such as glacial till and windblown loess develop characteristic weathering profiles. Zones in those profiles may be more permeable than others. The zones should be identified and characterized by composition and thickness. Weathering profiles for shallow depths (less than 10 ft) are usually presented in county soil survey maps and are discussed under "Mineral Resources."
Grain-Size Distributions	Grain-size analysis, conducted on samples from unconsolidated formations, yields the proportion of material for a specified size range. Range distributions can be used to estimate permeabilities, design monitoring wells and enable the hydrologist to better interpret stratigraphy. Such analyses are most often performed during preconstruction engineering/soils studies and may be obtained from local consulting firms in addition to other above-mentioned sources.

TABLE 4.6. Types and Sources of Hydrologic Information (EPA 1981)

Topic	Definition and Sources
Surface Drainage	Surface drainage information includes tributary relationships, stream widths, depths, channel elevations, and flow data. The nearest permanent gaging station and period of record are also determined. A USGS 7-1/2' Topographic Map will show some of the necessary information. Gaging stations and flow data can be identified and obtained through USGS data bases. (See Appendix A, Part 2 of *NEIC*.)
Ground- and Surface-Water Relationships	Streams near hazardous-waste releases can either receive ground-water inflow or lose water by channel exfiltration. Hydrologic literature is reviewed to determine if local streams are "gaining" or "losing." Losing streams are common in areas of limestone bedrock and those with arid climates and coarse-grained substrates. Potential ground-water recharge areas are also identified. Flat areas or depressions noted on topographic maps are suspect, while steep slopes normally promote runoff. Stereo-pair aerial photographs can be useful in these determinations (see Appendix A, Part 3 of *NEIC*). Irrigated fields detected in aerial photographs suggest recharge areas; swampy, wet areas suggest areas of ground-water discharge.
Underlying Aquifers	Information is collected to delineate aquifer type (unconfined, confined, or perched), composition, boundaries, hydraulic properties (e.g., permeability, porosity, transmissivity), and interconnection with other aquifers (direction of leakage). These data are generally available through USGS publications.
Depth to Ground Water	Used here, depth to ground water refers to the vertical distance from the ground surface to the standing water level in a well completed just below the water table. In a confined aquifer, the depth to water represents a point on a "piezometric" surface. The depths will limit the types of equipment that can be used for purging and sampling. Probable ground-water flow directions (both horizontal and vertical) are determined by comparing depths to water in a series of wells and piezometers that are all referenced to a standard datum. Data may be obtained from USGS and other data bases (see Appendix A, Parts 1 and 2 of *NEIC*).
Water/ Contaminant Contact	Possible ways that water could contact contaminants are studied to understand how pollutants are carried into the environment and to later design remedial measures. Possibilities include: • precipitation falling directly on spill materials • precipitation infiltrating through cover materials or soil • flood water (determine flood frequencies and elevations, compare to spill elevation) • ground water (compare elevations of contaminants and ground water). Pertinent information may be obtained from various records listed in Appendix A, Part 1 of *NEIC*.

TABLE 4.6. (contd)

Topic	Definition and Sources
Water Quality	Knowledge of natural or background water quality is required when monitoring for ground-water contaminations. The quality of surface waters is usually available from EPA, USGS, and state records (see Appendix A, Part 1 of *NEIC*). Ground-water data will probably be quite limited for any given area, but may be identified through USGS Water Resources Division offices, state geological surveys (see Appendix A, Parts 2 and 5 of *NEIC*), or state and county resource boards and health departments.

Obtain On-Scene Data

No matter what regional data are available, certain information must be collected or verified at the scene of a spill. Existing data give regional information on soil types and ground-water hydrology in varying degrees of detail. On-scene data verify the extent of contamination, and the probable speed and direction of the contaminant movement through the subsurface.

Important data to be collected at the spill scene are listed below and discussed in the following text:

- extent of contamination and transport speed in the soil layer
- depth to the water table and the direction of flow
- extent of contamination in the ground water
- transport speed in the zone of saturation.

The extent of contamination underground at a surface spill can often be seen in soil samples. A hand- or gasoline-powered auger may be used to bore a hole to take soil samples or to place sampling devices. Soil samples have the advantage of giving in-situ water quality measurements. They also can give an idea of the sorbtive capacity of the material in which the spill occurred. Lateral movement of the contaminant can be evaluated through careful areal placement of sampling points around the spill scene. Existing access points to the subsurface, such as pits and excavations should be examined for contamination and local soil properties. The potential for impermeable layers or layers of higher permeability should be carefully evaluated. Care must be taken during sampling operations to avoid cross contamination of aquifers or opening avenues of rapid transport.

Depth to ground water and samples of the ground water are required to evaluate the extent, if any, of contamination in the saturated zone, or the distance that the spill front must move to reach the saturated zone. The ground-surface elevation of the spill must be determined as accurately as possible. An aneroid barometer/altimeter is a quick way to establish elevations of the spill scene as well as of nearby

Obtain On-Scene Data (contd)

observation points with respect to the nearest monument. Existing wells should be located, measured for both water- and land-surface elevations, and sampled, if possible. (Private well owners should be provided with a copy of the sample results, whether the well is contaminated or not.) Samples should also be taken from seeps, springs, and gaining streams (those receiving ground water) in the vicinity of the spill. Ground-water elevations combined with information from the vadose sampling will indicate the distance from the spill to the ground water. Water levels from three or more wells will indicate ground-water flow direction because flow is always from high to low head. The piezometers must be completed at different depths within the ground water to determine the depth of penetration of the contaminant. When further investigation is necessary, standard drilling technology can be used for boring monitoring wells. (See references following this section—Ground-Water Monitoring, and USGS reports entitled Techniques of Water Resource Investigations.)

Evaluate Data

A primary concern during emergency response is knowing how, when, and where the contaminant will affect human population. When ground water is the potential transport medium for the contaminant, the velocity (speed and direction) of that flow must be known. Information associated with existing wells is most valuable and can be obtained through the well owners, well drillers, or the USGS. Specific capacity (the volumetric yield with time per foot of drawdown) can be used to calculate a rough permeability value. Porosity, which is also required to calculate velocity, can be estimated from information on the materials penetrated during drilling. Typical unconsolidated geologic media (usually found near the surface) are listed below in order of increasing retardation (sorptive capacity) or generally decreasing contaminant transport speed (EPA 1978):

1. gravel, medium to coarse sand
2. fine to very fine sand
3. sand with <15% clay; silt
4. sand with >15% but ≤50% clay
5. clay with <50% sand
6. clay

[For corresponding Unified Soil Classification System symbols, see EPA (1978), p. 18.] When liquid encounters less permeable layers, it will often follow alternate paths of less resistance and form new flow patterns (e.g., vertical movement or surface discharge). The geochemistry of the porous medium and the presence of organics also affect retardation of contaminant transport.

Consolidated rock materials (below the surface layer) are listed below in order of increasing retardation:

1. cavernous or fractured limestone, evaporites, factured basalt and other extrusive rocks
2. fractured igneous and metamorphic rocks (except lava), sandstone (poorly cemented)
3. sandstone (moderately cemented), fractured shale and limestone
4. sandstone (well-cemented) volcanic clastics (pyroclastics), scoria

Evaluate Data (contd)

5. siltstone
6. unfractured shale, igneous and metamorphic rocks.

Appendix A of *NEIC* lists published soil surveys in the U.S. See EPA (1978—p. 17) for a list of common driller terms used in estimating specific yield for these consolidated and unconsolidated earth materials. (The numbers—1 through 6-given above, correspond to I through VI on p. 17 of this reference).

Lower permeability means greater attenuation. The typical permeability for the unconsolidated and consolidated materials listed above may range from 3000 ft/day (1 cm/sec) to 3.0×10^{-6} ft/day (10^{-9} cm/sec). Primary permeability is a property of the pores of the material. Fractures, joints, and faults constitute the secondary permeability of a material and may be major pathways. Although much less fracturing is found with increasing depth, this will not be of significance in most spill situations. Layered materials are evaluated according to the most permeable zone, allowing for possible pathways and leakage through the less permeable layers. In homogeneous earth materials (i.e., without stratification or marked variations in pore-size distribution), the infiltration front is pear-shaped, with the larger portion at the bottom (Figure 4.7). The vertical component is due to gravity, whereas the horizontal component is due to capillarity. Capillarity is also a vertical phenomenon because the liquid sprawls as a function of gravity vs capillarity. The migration will take place by successive impregnation of large areas. In a permeable stratum, this penetration is mainly vertical; in a less permeable stratum, the liquid follows less resistant paths and the horizontal penetration increases. The heterogeneity of the subsoil influences the shape of the contaminated area, and can even cause splitting of the plume.

A zone that is capable of storing, transmitting, and yielding water in significant quantities, is called an aquifer. The transport capability of an

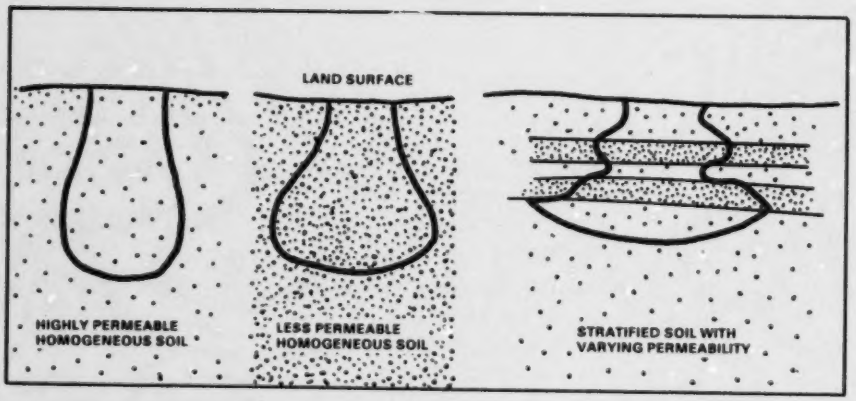

FIGURE 4.7. Generalized Shapes of Spreading Bodies (after Fussell 1981)

Evaluate Data (contd)

aquifer depends on its permeability, hydraulic gradient, and thickness. Unconsolidated and semiconsolidated material composed of sand or gravel will transport liquids much faster than sand with some clay or a clay with some sand (if the effective porosity and hydraulic gradients are the same). Consolidated material that has been fractured will usually transport liquids faster than unconsolidated sediments. Also, longitudinal dispersion tends to be greater and the front of the contaminant exhibits a pattern known as fingering. The pattern is common for layered systems with markedly different permeabilities in unconsolidated materials.

Aquifers are classified as confined or unconfined, depending on the absence or presence of a water table (phreatic surface) at atmospheric pressure. Confined aquifers (also called artesian or pressure aquifers) are under pressure and are bounded above and below by impervious material. Unconfined aquifers have the water table as an upper boundary of saturation and are most susceptible to contamination from surface spills via the vadose zone.

Leachate plume tends to remain as an intact body within the ground-water body with only slight dispersion and diffusion along the edges. Hydrodynamic dispersion, dielectric properties, and viscosity may cause certain leachate constituents to move faster than the average ground-water velocity, although plume direction in most instances will follow general ground-water flow. In general, ground water flows from higher topographic areas toward surface water (which is a discharge area); however, site geology such as impermeable layers and heavily pumped wells can drastically alter flow direction (Figures 4.8 and 4.9).

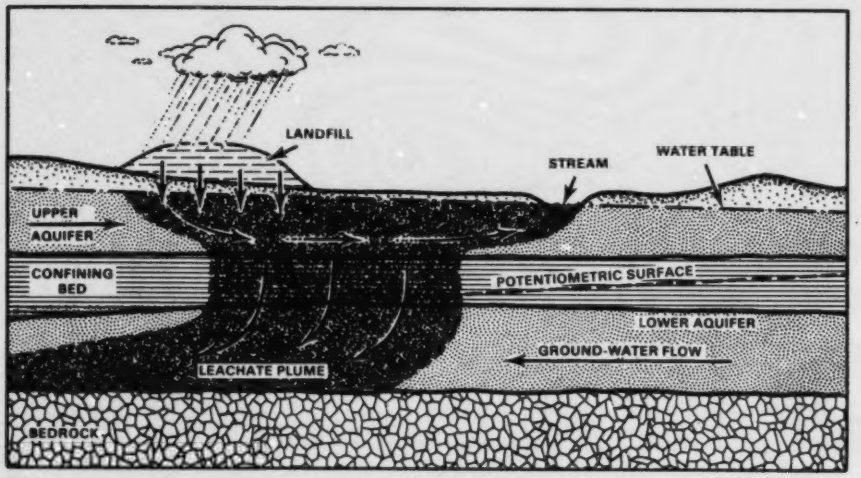

FIGURE 4.8. Two-Aquifer System With Opposite Flow Directions (EPA 1981)

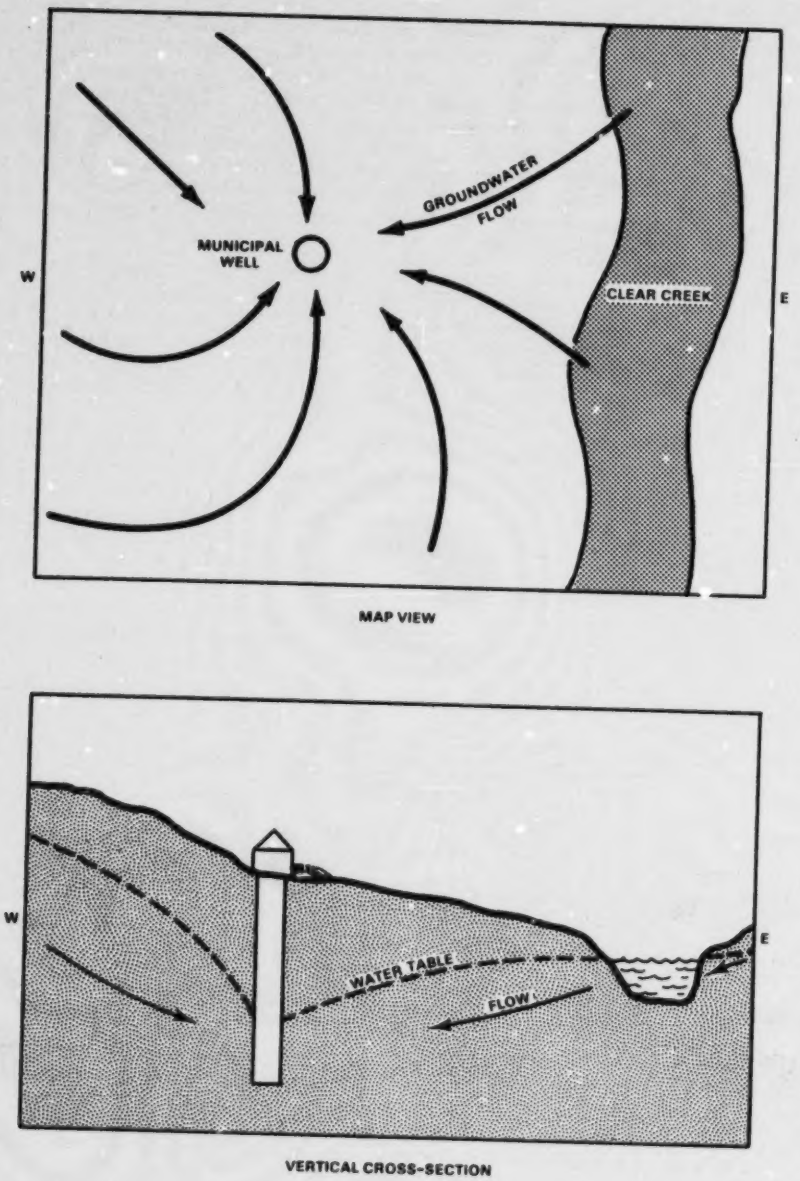

FIGURE 4.9. Ground-Water Flow Affected by a Pumped Well (EPA 1981)

Evaluate Data (contd)

Under certain conditions contaminants may move up-gradient by diffusion or by buoyant flow. These conditions include significant density differences (contaminant lighter than water), high ground-water gradient (at unsaturated/saturated interface), and low ground-water velocity.

The depth of a plume normally increases with distance from the spill. Hydraulic and lithologic conditions, as well as leachate density, control the actual depth to which the contamination will travel. Retardation has varying effects on the movement of different leachate constituents due to interactions of the medium with certain chemicals.

Geophysical Methods of Surveying

Geophysical surveying, sometimes referred to as nondestructive testing (NDT), is useful in determining subsurface hydrogeologic features such as water-bearing strata and discontinuities in lithology (Lord, Tyagi and Koerner 1980). It does not require extensive soil borings. The NDT methods can also be used to detect and monitor subsurface liquid spills. The methods are listed and described in Table 4.7, with additional references listed in the following reference section. Table 4.7 indicates which of the following problem areas may be or have been addressed by each method. (The numbers below are used in the table.)

1. Downstream ground-water pollution and soil contamination exists that must be mapped in vertical and horizontal planes.
2. Spill tracing near the surface must be done to map the extent of the infiltration of a surface spill.
3. Buried containers must be located.
4. The configuration and composition of buried containers must be assessed before handling and removal to proper disposal.
5. Leaks in gravity flow and pressurized pipelines must be located.

TABLE 4.7. Problem Areas Rated Against Possible NDT Methods of Solution (1 = highest potential, 5 = lowest potential, blank = not applicable)

NDT Method	Description	References in Addition to a, b, c,d	Problem Area: (1) (2) (3) (4) (5) (see above)
Pulsed Microwave	Commercially available system, surveys to 10 ft quickly over large areas.	e,f,g,h,i	2 2 1
CW Microwave	Soon to be available, same as above except that microwave is continuous instead of pulsed.	j,k,l,m	2 2 1
Eddy Current	Works on the principle of metal detectors; many types available commercially.	y	2 2

TABLE 4.7. (contd)

NDT Method	Description	References in Addition to a, b, c,d	Problem Area: (1) (2) (3) (4) (5) (see p. 4.47)
Magnometer	Measures changes in earth's magnetic field, which is altered by iron, steel, etc. CA*	y	3 4
Seismic Reflection	Impulse on surface or below will cause return waves characteristic of subsurface. CA*.	x	4 4 5
Seismic Refraction	Time is measured from impulse to transducer to indicate depth to change in lithology. CA*.		4 4 5
Electrical Resistivity	Current applied to ground and electric potential is measured at surface. CA*.		3 3 5
Penetrating Radiation	X-rays, γ-rays or neutrons passed through material to detect changes. CA*.	n,o,p,x,y	3 2 5
Acoustic Emission	Noises monitored on materials under stress and related to stability. CA*.	q,r	1
Liquid Penetrant	A liquid is applied to a material, excess removed, powder applied to mark cracks. CA*.	n,o,p	4
Infrared Radiation	Radiation patterns reveal heat flow anomolies and structural flaws. CA*.	p,s	4 4 4 4 3
Ultrasonics	Elastic energy pulse is reflected by cracks and discontinuities in a material. CA*.	o,p	5 5 2 2
Sonar	Pulse of acoustic (sound) energy to probe bottom of water bodies. CA*.	t	5 5
VLF Electromagnetic and Resistivity	Measurement of secondary electromagnetic fields indicates variations in subsurface.	u,x	3 4 5
Induced Polarization	Uses a strong primary current to locate materials with certain ionic exchange properties such as saturated clays.	u	5

* CA = commercially available.

Numerical Modeling

Two- and three-dimensional mathematical models of saturated flow can be employed to evaluate alternatives for cleaning up large spills over diverse areas. A preliminary prediction of contaminant plume movement will aid in determining the most useful sampling sites.

An increasing number of codes are being developed on a larger scale for potable aquifers across the United States; thus, many areas have been modeled. Models that have been developed or calibrated for a particular aquifer should be used when available. Between-response activities may include model runs (using typical contaminant chemicals and spill situations for existing aquifers) to give an indication of travel times and contaminant concentrations in the environment. Local consulting firms, laboratories, and universities with site-specific experience in these activities should be employed if the cost can be justified. Modeling groups in these organizations will have codes adaptable to most ground-water situations. An experienced person may also be able to find a usable code through one of the following centers:

Argonne Code Center
9700 South Cass Avenue
Argonne, Illinois 60439
Attn: Mr. Louis Ranzini (312) 972-7250

International Groundwater Modeling Center
Holcom Research Institute, Butler University
Indianapolis, Indiana 46208
Attn: Paul K. M. vander Heijde,
Principal Investigator (317) 283-9667

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Underground Contamination—Water Tracing

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4.3 ECOLOGICAL ASSESSMENT CHECKLIST

ACTIVITIES BEFORE OR BETWEEN RESPONSES

1. Prepare a list of scientific advisors available to the OSC—name, telephone number, organization, expertise (see p. 4.63).
2. Obtain maps of the region that locate population centers (see p. 4.61).
3. Arrange to obtain the following information when available or as the need arises (see p. 4.61-63):
   - regional land-use maps
   - water-well and surface-pumping maps
   - water-use characteristics
   - lists of schools, hospitals, and other institutions that must be notified in the event of imminent health hazards or an evacuation.
4. Gather maps locating environmentally sensitive areas (see p. 4.63).
5. Assemble a list of endangered species— mark habitats on maps (see p. 4.63).
6. Compile a list of names and addresses of damage assessment services. (see p. 4.63).

ACTIVITIES DURING RESPONSE

1. Photograph and describe the incident (see p. 4.63).
2. Sample affected biota (see p. 4.63-64).
3. Compile a chronological log of observed effects and location of occurrence. (see p. 4.64).

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4.3 ECOLOGICAL ASSESSMENT

An evaluation of human, animal, and plant populations surrounding the scene of a release of a hazardous substance can provide valuable information concerning the sensitivity of the environs to pollution. In an emergency situation, concern for human populations will be paramount; the disruption of other species will usually be of secondary importance. For instance, if a tank car rupture spills benzene into a tributary leading to a potable water supply reservoir, mitigation efforts will be geared toward preserving potable water supplies; fish and wildlife kills will not be as immediate a concern. Characterization of the ecology of an area should, therefore, emphasize factors that contribute to human health and welfare. These factors may be thought of as "receptors" that are connected by potential "pathways" (for instance, surface-water transport) to the emergency incident. By investigating potential receptors as well as toxicological data and data relating to the extent of potential exposure, the severity of the effects of a release can be estimated.

Much of this information can be collected before or between incidents. If the data are collected and maintained in a comprehensive manner and are available, the ecological assessment of an incident can be conducted quickly. Once an emergency occurs, provisions should be made to obtain samples designed to document the incident and to determine the need for followup monitoring programs.

DATA REQUIREMENTS

Information required to characterize an area in terms of the potential for long-term environmental disruption in the event of a release of hazardous substances includes:

- density and distribution of human populations
- locations of hospitals or other institutions that may require special attention
- land-use characteristics
- water-use characteristics
- distribution of water wells
- distribution of surface-water supplies
- endangered species or critical environments.

Most, if not all, of the information described in this section can be gathered ahead of time to be readily available to the response team in the event of an emergency. Consult state and local contingency plans for this type of data. Additionally, the response team should be familiar with local experts and scientific advisors who could be called upon in an emergency.

Identify the Density and Distribution of Human Populations

Often the size and location of the population at risk have a direct bearing on the choice of a mitigation measure. Rough, large-scale data on population distributions can be gathered from current topographic maps or aerial photographs. More site-specific information may be gathered from zoning maps, local planning agencies, or local housing officials or census officers.

Once an incident has occurred, certain site-specific information will be necessary to determine the risk of exposure to offsite residents. Characterizing the offsite buildings nearest the location of the emergency, in terms of distance and direction, is especially important if a fire or explosion hazard exists. These buildings may need to be evacuated.

Locate Institutions That May Require Special Attention

Hospitals, schools, jails, and other facilities that may present problems in the event of an evacuation should be located before an emergency occurs. Such facilities can be indicated on reference maps and should be immediately available to the OSC. They can be located through telephone listings, maps or photographs, and through local planning agencies and chambers of commerce.

Identify Land-Use Characteristics

The choice of a mitigation measure may depend on the current and projected uses of the land surrounding the scene of an incident. For this reason, up-to-date land-use maps of the area should be available. These maps can be drawn to show urban, residential, and agricultural areas, and other points of interest to the response team. Such maps may be used to assess possible impacts of alternative mitigation measures (e.g., to determine downstream or downwind activities that may be affected). The choice of a treatment method may depend on the land use adjacent to the scene (e.g., prime farmland versus open range). The land use of an area can be determined from maps or photographs obtained from zoning departments (often located in county assessor's offices) or from state agriculture or commerce departments. Land-use plans may need to be modified to minimize contact with residual substances.

Identify Water-Use Characteristics

Once the population characteristics of an area are determined, the means by which residents of that area obtain their water should be investigated. If, for instance, a town is supplied solely by ground water, the implications of an emergency involving leaching into aquifers are more serious than if that same town were supplied by a reservoir. Water-use maps, analogous to land-use maps, can be compiled for an area; both public and private water supplies should be included. This information can be obtained from sources such as public health departments, water supply companies, well drillers, and residents of the area. In addition, analyses that have been performed on these water supplies should be identified, and copies of all data should be requested.

If an area is serviced by a public water supplier, the type of treatment system used should be identified. If possible, the locations of water mains should be determined, as these could provide entry points for polluted ground water. Information should also be gathered on local sewer and storm-drain systems to determine possible infiltration or illegal discharge points.

Identify Distribution of Water Wells

When an emergency occurs, the distance to the nearest offsite well should be known in the event of possible ground-water contamination. If the locations of water wells within the area of interest are catalogued beforehand, determinations of plume movement could be made quickly. Any results of prior analyses on these wells should also be collected. This information may be available from state or county mining or water-resources agencies, water supply companies, or public health departments.

Identify Distribution of Surface-Water Supplies

The response team should be familiar with the patterns of the drainage basins within its jurisdiction and with the locations of water withdrawal and pump stations along water courses. This information can be obtained from USGS topographic maps or reports, aerial photographs, or water supply companies.

Determine Endangered Species or Critical Environments

Areas where releases of hazardous substances are capable of doing the most harm to natural populations should be characterized. These locations may include national or state parks, habitats of threatened or endangered species, national wildlife refuges, national or state forests, fish and wildlife management areas, wetlands used as breeding grounds, coastal areas where spawning or breeding takes place, commercial fishing or shellfish harvesting areas, or areas overlaying sole-source aquifers. This information can be gathered in advance of any emergency action. Many sources of information are available for a given locality: state and local environmental agencies should have comprehensive listings of such areas, and the U.S. Fish and Wildlife Service and state departments of fish and game should be able to supply baseline information on wildlife distributions. Regional, state, and local contingency plans for oil and hazardous substance spills may also contain valuable data.

SAMPLING AND ON-SCENE DATA GATHERING

On arrival at the incident, the response team must initiate several actions to insure that the OSC has the information needed to make decisions and to insure that a complete record of the incident is available in the event of litigation. Although the OSC and the onsite response team may not be involved in the damage assessment process, they may contribute to the collection of evidence for future legal proceedings.

Conduct an Initial Survey

On arrival at the scene, a determination must be made as to whether any samples or observations need to be taken immediately to prevent the loss of evidence. For an ecological assessment, this may include sampling dead fish (which may otherwise be lost through water movement) or sampling biota directly in the path of the pollutant stream (to determine before-and-after effects). The behavior of resident populations should be observed (e.g., fish gasping at the surface of a stream) as well as the appearance of plants and animals in the area (e.g., the extent of initial damage to vegetation). Photographs can supplement notes and sampling logs. Because every incident is different in character, observations and sampling procedures will vary. First observations, however, should focus on immediately apparent abnormalities. Someone with a thorough knowledge of the local area (a game warden, state biologist, or resident) may be more likely to note recent changes. Professional analytical and damage assessment services may assist in the sampling and analysis portions of the response action. A list of such services can be compiled beforehand and made available to the OSC.

If a continuing data-gathering effort is required, an appropriate sampling strategy will be needed. The chosen strategy should include sampling of affected and unaffected (control) points. Enough points should be sampled so the sampling variance can be estimated. Possible strategies to be chosen include paired control, randomly stratified, or randomly or regularly spaced sample points. References for these strategies and others are listed in the reference section

Conduct Sampling Activities

Response teams should assume that all sampling results could be used in future legal proceedings. Manuals currently exist that describe the materials and methods to be used to obtain reliable data. (These

Conduct Sampling Activities (contd)

manuals are listed in the following reference section.) In general, when selecting a sampling method, the following points should be considered (EPA 1972):

- Is the method technically defensible, generally accepted and quoted in standard texts (such as those in the following reference section)?
- Is the method suitable for collecting statistically sound samples?
- Is the method suitable for gathering test and control samples?
- Will the team be able to collect adequate samples with the manpower and time available?
- Is the method able to give quick preliminary results?
- Is the method adequate for economically important species?
- Is the method the best for documenting the incident?
- Is the method one that the team is accustomed to, and prefers to use?

High standards of performance, care, and documentation are as important as a standardized method in ensuring the quality of the data gathered. Consistently uniform procedures are especially important if statistical evaluations of the data are to be undertaken.

Assess Alternative Mitigation Measures

Following a characterization of the incident and after the ecological implications of the problem have been described, responses to the emergency can be considered in terms of possible effects (both beneficial and negative) on the ecology of the area. In an emergency situation, a detailed tradeoff analysis may not be possible, and decisions may be made on the basis of previously gathered, immediately accessible data.

Alternative mitigation measures can be compared in terms of reduction of risk to human and other populations. Some of the questions to be asked are:

- What ecological impacts (based on current knowledge) can be projected if no action is taken? (This may imply mitigation of the problem by natural dispersion and/or dilution.)
- If a certain mitigation measure is chosen, what level of cleanup will be necessary to insure a beneficial effect on the environment (i.e., to reduce the severity or duration of exposure sufficiently to lessen impacts compared to what would happen if no action were taken)? Are these benefits worth the time and money to be spent?
- If the hazardous material is to be transported offsite, what are the ecological implications of disposal at another area?
- Will any restoration efforts be required? For instance, should dead fish be removed from an area to prevent other species that may feed on the fish from being affected? How long will it take for an affected area to recover?

The above questions illustrate the difficulty of the process; many decisions have to be made by the OSC on the basis of qualitative data, frequently under circumstances that do not allow for the gathering of sufficient information. For this reason, and because the process of choosing an alternative may be questioned later, the data on which the decision is based should be documented.

Monitor Populations During the Mitigation Process

Observation and monitoring of natural and human populations should continue during the mitigation operation. Such monitoring data will help the response team determine whether cleanup efforts should be continued or whether mitigation is complete. Data gathered during this period should be used to document the effects of the mitigation effort and form the basis for a longer-term monitoring effort, if such an activity is required.

Ecological assessment activities during this phase should be geared toward answering the following questions:

- Did implementation of cleanup activities have any immediate effect on the ecology of the area? (For instance, were people able to move back into their homes immediately after a tank car leak was repaired?)
- Are any segments of natural populations not responding immediately, and if so, can estimates be made of when those populations may return to normal? (For instance, when may a stream bed be expected to be recolonized?)
- Were any agricultural or fishery resources damaged, and if so, when may these be expected to recover? (For instance, if an oyster bed is killed, when may it be reseeded?)

Obviously, information may not be available to answer these questions during a cleanup operation. If that is the case, the data and conclusions that have been collected up to that point should be used as input to the design and implementation of a monitoring program. Such a program would measure the progress of the ecological systems of concern against expected rates of recovery and against the future uses expected for the area. If such studies show that the system is not recovering as expected, additional cleanup and restoration efforts may be considered.

Any information gathered during the emergency cleanup activity should be made available to those who are to perform after-the-fact monitoring surveys and long-term observations of the area. Communications between the scientific support staff and these groups should be maintained to provide a complete record of the incident.

ECOLOGICAL ASSESSMENT REFERENCES

Sampling

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Weber, C. I. 1973. *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents.* EPA-670/4-73-001, Environmental Research Center, Cincinnati, Ohio. (A detailed treatment of sampling and analysis.)

Damage Analysis

EPA. 1979. *NEIC Policies and Procedures Manual.* National Enforcement Investigations Center, U. S. Environmental Protection Agency, Denver, Colorado.

4.4 TOXICOLOGY, HEALTH, AND SAFETY CHECKLIST

ACTIVITIES BEFORE OR BETWEEN RESPONSES

1. Obtain or arrange access to standard toxicological references or computer systems.
2. Locate lists of priority pollutants and other hazardous substances as defined in the laws.
3. Obtain a copy of the National Fire Protection Handbook or similar reference on flammable and volatile substances.
4. Compile a list of scientific advisers and local or regional officials who may provide assistance during an emergency response.
5. Have population and critical habitat maps available for determining potential exposures.
6. Develop a generic emergency evacuation plan.

ACTIVITIES DURING RESPONSE

1. Observe situation for immediate explosive, flammability, or reactive dangers (see pp. 4.69-70).
2. Review the tentative substance analysis and determine whether it is defined as hazardous (see pp. 4.70-71).
3. Determine from the references whether (see pp. 4.69-70):
   - a flammability hazard exists
   - the substance reacts violently with water
   - the substance may react violently if it comes in contact with other nearby chemicals.
4. Determine if the substance is a probable toxicological hazard by reviewing (see pp. 4.70-71):
   - any evidence of a fish kill or other obvious effects to wildlife
   - the mammalian criteria limits for acute toxicity
   - the aquatic 96-hr LC50 for the substance, noting whether it is greater or less than 500 mg/l
   - whether it contains carcinogenic, mutagenic, or teratogenic substances
   - whether it is particularly persistent or bioaccumulative
   - whether the quantities are large enough and a mechanism exists that would reasonably pose a toxic hazard.
5. Determine the human health hazard by evaluating (see pp. 4.72-73):
   - the proximity to populated areas
   - inhalation potential based on the volatility of the substance and the local meteorology
   - location of drinking-water sources and potential contamination from leaching or runoff.

4.4 TOXICOLOGY, HEALTH, AND SAFETY

The primary purpose for emergency response to a real or potentially hazardous incident is to protect public health. The public is assumed to be those populations adjacent to the scene, whose drinking water supply may be subject to contamination as a result of the incident, or those populations within an area that may be exposed to airborne or waterborne contaminants.

Immediate health or safety hazards (aside from highly infectious agents) may be of two types: 1) chemicals that cause a hazardous physical response (e.g., those that are particularly flammable, explosive, corrosive, or highly reactive), and 2) highly toxic chemicals (which also may be flammable or explosive). Because both types of hazards are more severe near the scene, the investigative and cleanup personnel are in the greatest danger of suffering negative health effects. A number of plans and manuals already exist that discuss worker safety; thus, these concerns are only briefly described here. (Some of these manuals are listed in the following reference section.) This discussion focuses on health hazards to the nearby public, with some attention to plant and animal toxicity.

When approaching a scene where the hazardous substances have not been identified, full safety measures are in effect and the emergency response team must assume that the release constituents are flammable, explosive, reactive, and extremely toxic until and unless they are proven otherwise. When the substance is known, precautions can be tailored to the characteristics of the chemical. If there is any suspicion that a radiation source may be involved in the incident, a radiation survey should be conducted. The use of indicator tubes and volatility meters to monitor for volatile organics or poisonous gases is definitely recommended.

The toxicological study objective is to determine whether the situation presents a current or future health or safety hazard, so that decisions on mitigation methods and public protection measures can be initiated. This assessment requires answers to the following questions to determine the hazard status of the substances:

- What are the substances?
- Are they flammable, explosive, or highly reactive (alone or in mixture)?
- Are they considered toxic chemicals?
- At what concentration are the materials hazardous?
- Are they present in hazardous concentrations or conditions?
- Is there a current or imminent health or safety hazard to the surrounding populace or to critical habitats?
- What are the probable effects without mitigating measures?

EVALUATION

Identify the Substances

An unidentified substance must be assumed to be both a chemical and a toxicological hazard (unless there is hard evidence to the contrary). Full safety precautions will be required of all personnel at the scene at least until the substance is identified (as described in the Chemical Characterization Section).

Determine if the Substances are Flammable, Explosive, or Highly Reactive

If the contents are already burning, have exploded, or are obviously undergoing a chemical reaction, go to the next question in the evaluation. If not, such reactions should be considered, particularly because they tend to spread materials that would otherwise be contained. First, the flammability and explosive nature of the chemical must be checked.

Determine if the Substances are Flammable, Explosive, or Highly Reactive (contd)

Quick sources of this information include CHEMTREC, Sax (1979), CHRIS, (U.S. Coast Guard 1974), DOT's Emergency Guide, NFPA, and Plunkett's Handbook (see following references). Information regarding the material's parameters (see Chemical Characteristics Section) such as flammability limits (Sax 1979; CHRIS—U.S. Coast Guard 1974), volatility, ignitability, flashpoint (CRC), and possible ignition sources that could start a fire, will help tailor the evaluation of the situation. Next, whether (and how well) the release is contained must be determined. If flammable chemicals are totally contained, for example, the immediate risk of fire is greatly reduced.

If flammable volatiles are not contained, and are of sufficient concentration and temperature to spontaneously ignite or are carried by air currents to an ignition source, vapor could begin burning over inhabited areas, timber, or critical wildlife habitats. Heavy vapors that are not contained could find their way to sewer lines or to chemicals with which they could react. Flammable or explosive chemicals washed down storm sewers could cause later fires or explosions.

Explosive and highly reactive chemicals pose concerns similar to those posed by flammable chemicals, in that they create a physical hazard and further disseminate the hazardous substance. Reagents that are reactive with water obviously should not be washed down. Containers should be scrutinized carefully to detect any leaks. Chemicals that are incompatible with the identified hazardous substance should be removed if stored or found near by. A compatibility chart can be found in the back cover pocket of Hatayama et al. (1980). Other sources of information on the potential hazards are given in the following reference section.

Determine if the Substance is a Toxic Chemical

Toxicity is the capacity of a substance to produce injury when it reaches a susceptible site in or on the body. Toxic responses are generally from exposure by inhalation, ingestion, or skin contact. Although every chemical is probably toxic to some extent, the concern is with chemicals that are moderately to severely toxic or are carcinogenic, mutagenic, or teratogenic. To determine whether the chemical has been legally defined as hazardous, the EPA/Coast Guard lists of priority pollutants and hazardous materials should be consulted [see TSCA, RCRA, CERCLA, Clean Air Act, FWPCA (Clean Water Act) following in reference section]. CERCLA defines pollutants and contaminants as materials having specific health, reproductive, or genetic effects on man or other organisms. To determine the relative toxicity of the chemical, sources such as the Registry of Toxic Effects of Chemical Substances, Sax (1979), CHEMTREC, CHRIS, and OHM-TADS provide pertinent information. The manufacturer's industrial hygienist may provide published toxicity data on the substance. (CHEMTREC may be able to provide the name of the manufacturer.) Some of the terminology used in toxicology follows:

Acute exposure usually refers to a single exposure lasting from seconds to about 96 hours. It can be used to describe exposure by inhalation, ingestion, or absorption through the skin.

Subacute exposure is of intermediate duration, between acute and chronic, and generally indicates exposures up to 90 days.

Chronic exposure describes exposures of long duration or sometimes describes frequent exposure.

Determine if the Substance is a Toxic Chemical (contd)

There are many descriptors of toxicity. Some of them are listed below:

LC_{50} - median lethal concentration (causing death of half the experimental population)—usually in mg/l units.

LD_{50} - median lethal dose causing death to half the population—usually as mg chemical/kg animal.

EC_{50} - median effective concentration necessary to produce a specified effect on half the experimental population.

TL_m - median lethal threshold—approximately equal to LD_{50} or LC_{50}.

TLV - threshold limit value—a somewhat arbitrarily set value above which adverse effects may result following continued or repeated exposure—usually as mg/m^3 or ppm for airborne concentrations.

TLV-TWA - TLV—time weighted average for normal 8-hour work day or 40-hour work week for repeated exposure without adverse effects.

TLV-STEL - TLV—short term exposure limit—maximum concentration continuously up to 15 minutes without causing intolerable irritation or permanent injury, or reducing worker awareness.

TLV-C - TLV ceiling—not to be exceeded, even momentarily.

MATC - maximum acceptable toxicant concentration—highest concentration not known to cause toxic effects.

IDLH - Immediately dangerous to life or health; any atmosphere that poses an immediate hazard to life or produces immediate irreversible debilitating effects on Health (ANSI 1980).

In some cases exposure may cause no immediately detectable symptoms but may result in delayed responses such as from agents known to be carcinogenic, mutagenic, or teratogenic. Reduction of contamination potential to near zero is especially important with these chemicals, as no threshold has been established below which no adverse effects result.

Determine At What Concentration the Chemical Is Hazardous

Some reference sources give experimental toxicity values in rats or other test animals, and in some cases they give estimates of the dose/concentrations for humans. Other sources will give relative values [such as the code in Sax (1979)—see following reference section—0 = no toxicity, 1 = slight toxicity, 2 = moderate, 3 = severe, and U = unknown or suspect data]. Much of the inhalation data, such as the TLVs, have been generated for occupational exposure. The data can be used as guides in approximating the inhalation hazard at locations where the air concentration can be analyzed or estimated. However, the TLVs do not necessarily reflect life-threatening concentrations and should be used cautiously when distinguishing between safe and unsafe levels of chemical exposure. Sensitive individuals may be injured at concentrations lower than would be suspected according to the available data.

Determine if the Chemical is in a Hazardous Concentration or Condition

The state of the containers or other barriers in the area should be examined. (Are the sides of the tank car or barrels bulging as if they may explode? Has a breached lagoon barrier left a clear path to the river? Do organic volatiles register on a meter or on detector tubes?) The chemical

Determine if the Chemical is in a Hazardous Concentration or Condition (contd)

properties of the substance will help to determine which route of exposure to humans is most probable. For example, a chemical with a high volatility is more likely to be an inhalation hazard than is a chemical with low volatility. A liquid with low volatility is more likely to filter through a soil profile or to follow a storm sewer. A solid or sludge is much less likely to be an emergency problem. Compare the estimated chemical concentration (see Chemical Characterization Section) with the toxic concentrations to determine whether the levels are toxic.

Identify Impending Health or Safety Hazards to the Surrounding Populace

If a chemical presents a potential airborne contamination problem, the following information will be necessary to estimate the hazard (much of which has been discussed in earlier sections):

- distance to the population or habitat at risk
- wind direction
- wind speed and variability
- quantity of toxicant lost through explosion or vaporization
- probability of rain
- conditions in which the substance would "fall out"
- duration of exposure
- concentration levels known to cause effects from inhalation, ingestion, or skin contact
- levels known to be fatal to man
- dilution and dispersion patterns.

Comparisons of the estimated air concentrations (reaching a population of concern) with TLVs will help guide decisions as to whether the concentrations are acceptable and whether the initial "slug" of contaminant has already passed over.

Drinking water contamination is the next major concern. One route for water supply contamination is the leaching or leaking of toxicant into ground water that is tapped for drinking water. While waiting for analytical results confirming contamination or the absence of contamination, information that needs to be gathered includes:

- location of any drinking water aquifers in area
- location of any private or abandoned wells nearby
- recharge rates of aquifer
- quantity of toxicant lost to soil
- soil characteristics and chemical characteristics of contaminant (to determine potential for soil attenuation—as Kd or other measure of sorption potential) or chemical mobility (using K_{ow}—octanol-water—coefficient ratios for which values <100 tend to be mobile and >100 tend to be bound in soil). See Chemical Characterization Section for further information.

Contamination of drinking water in surface-water impoundments can result from 1) migration of the chemical in runoff from the site to

Identify Impending Health or Safety Hazards to the Surrounding Populace (contd)

the water supply, 2) movement of contaminated ground water feeding surface water, 3) precipitation of previously suspended contaminant into or around a water body (e.g., acid rain), and (rarely) 4) in the carcasses of contaminated animals in contact with the water.

To estimate the potential migration to the stream or another water body, the investigator will need this information:

- precipitation since the incident
- nearness of the water body to the incident site
- recharge rate of surface water by ground water
- mobility of the contaminant (i.e., is it heavier than water? suspended in water?)
- concentration of contaminant after dilution
- surface runoff rate.

Ingestion of the toxicant may be accidentally "accomplished" by three main pathways—ingestion of contaminated drinking water, ingestion of tainted fish or wildlife, or ingestion of tainted produce that was in the path of the plume. Depending on the concentration of the contaminant and on the mode of ingestion, a toxic response could result.

Exposure can also occur through direct contact with the released material or through contact with contaminated surface waters. Depending on the contaminant and its concentration, a local or systemic toxic response could occur.

Special Problems

Unless the incident concerns a release of a single chemical and is isolated from other potentially hazardous materials, a variety of chemicals and their accumulative toxicities will probably be involved. The effects to organisms exposed to a combined source of hazardous material may be additive, synergistic, or antagonistic. Unless the mixture reacts to form known compounds, predicting toxic effects involves more guesswork than usual. Also, only one chemical may be initially involved in an emergency incident, but the chemical may degrade to one or more compounds of differing chemical and toxicity properties.

Although personnel safety is of extreme importance, an adequate discussion of this aspect can be found in several of the references and will not be repeated here.

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Computer Bases

CHEMLINE - Bibliographical

MFDLINE - Bibliographical

OHM-TADS

RTECS

TOXLINE - Bibliographical

CHEMTREC - Chemical Transportation Emergency Center - CMA Phone (800) 424-9300

INFORMATION SOURCES FOR TOXICOLOGY, HEALTH, AND SAFETY

	Potential Hazards				
	Flammable	Explosive/ Reactive	Toxicity	Distance to Evacuate	Safety Guides
DOT - Emergency Guide	X	X		X	X
TLV guide - ACGIH			TWA/STEL		
Documentation of TLV			X		
Sax	X	X	X		X
Registry of Toxic Effects (RTEC)			X		X
Plunkett-Handbook	X		X(general)		X
CHRIS Manual	X	X	X		X
CHEMTREC	X	X	X		X
OHM-TADS-Computer and hard copy	X	X	X		
Merck Index			X (some)		
MEDLINE, CHEMLINE, TOXLINE	computer data bases requiring a terminal to scan the literature - no actual toxicity values are given				
Water Quality Criteria			X		
MCA Safety Manual					
Hazardous Chemicals Data	X	X	X		
EPA Field Detection	X	X	X (general)		X
Priority Toxic Pollutants			X		
MEGS	goals for emissions limits - ambient levels				
Hatayama et al.		X			
Hazardous and Toxic Effects (Sitting)			X		X
NFPA - 2 handbooks	X	X			
OSHA - Flammable	X				

4.5 IMPACT ANALYSIS OF MITIGATION METHODS CHECKLIST

ACTIVITIES BEFORE OR BETWEEN RESPONSES

1. Determine what hazardous materials are most likely to be involved in an emergency.
2. Identify mitigation methods that are effective on those materials.
3. Obtain information on those methods.
4. Identify possible environmental impacts from those methods.
5. Investigate changes in mitigation methods and procedures to reduce environmental impacts.

ACTIVITIES DURING RESPONSE

1. Obtain environmental information needed to characterize the unplanned release.
2. Identify environmental impacts of each suggested mitigation method.
3. Provide information on mitigation methods and other scientific support as needed.
4. Monitor environmental impacts during cleanup and compare actual impacts to predicted impacts.

ACTIVITIES FOLLOWING RESPONSE

1. Monitor the site for long-term impacts.
2. Document environmental impacts from mitigation methods.
3. Analyze the response and suggest improvements in methods.
4. Obtain additional information useful for future responses.

4.5 IMPACT ANALYSIS OF MITIGATION METHODS

An impact analysis should assist the selection of a mitigation method that will result in the most favorable environmental impacts. This section discusses the possible consequences of the mitigation methods, which are performed by the OSC. To assist the OSC, scientific support should be available to: determine environmental impacts of releases, identify mitigation methods, and characterize environmental impacts during and after mitigation. Some examples of possible environmental impacts are given below.

Example. Ammonia gas is leaking from a tank car and may affect people downwind. It can be removed from the air by water sprays, but that water may then be toxic to fish.

Example. Hazardous chemical X is reacting with air or water inside a leaking drum. Sealing the drum will stop the leak but the reaction may continue. If enough pressure builds up, the drum may explode.

Example. Hazardous chemical Y is leaking from a corroded drum and may contaminate surface water. If the liquid is contained by a dike, the soil may become contaminated and subsequent contamination of ground water may result.

Example. Hazardous chemical Z is leaking from a tank car into a small pond. If the chemical is removed from the water by carbon adsorption, the contaminated carbon must be regenerated or disposed of.

In addition, personnel responding to a release of hazardous materials are endangered by the very nature of the material released and by their presence at the site, Also, the response can introduce hazards associated with equipment-related accidents. The mitigation methods discussed in this section are divided into four categories: containment, chemical alteration, physical separation, and disposal/recycling (see Table 4.8).

CONTAINMENT

Containment, or stopping the flow, is usually the first mitigation step at an emergency response. Methods and impacts depend on whether the hazardous substance is a solid, liquid, or gas, and whether it is located on land, in water, or in the air.

Stop Further Flow

In some cases, flow may be stopped by closing a valve or by changing the position of the tank or drum. Holes in drums or tanks may be patched or caulked with a variety of materials, including putty, concrete, foam, wood, fabric, tape, solder, and oakum. A foam plugging device that expands to fit the hole has been developed for the U.S. EPA (Cook and Melvold, National Conference on Hazardous Material Spills—EPA 1980). Smaller containers may be enclosed in larger ones. Flow may be collected in drums or bags. Material released before the seal is effective, however, must be controlled by another mitigation method.

Possible negative consequences of mitigation methods may include:

- the release of hazardous substances to the environment as a result of sealing agent failure (due to an improper seal or a reaction of the sealing agent with hazardous chemicals or containers)
- releases caused by failure of the container (due to continued corrosion or additional damage)

TABLE 4.8. Mitigation Methods

Containment	Chemical Alteration	Physical Separation	Disposal
Stopping the flow	**Uncontrolled Combustion**	**Carbon Adsorption**	**Secure Landfill**
Vapor Control	**Incineration**	**Resin Adsorption**	**Recycling**
Cooling Source	**Biological Degradation**	**Ion Exchange**	
Reduction of Surface Area (foams, film, sorbents)	Natural	**Reverse Osmosis**	
Water Spray	Land-Farming	**Gravity Separation**	
Dilution and Dispersion	Small-Scale Reactors	**Dissolved Air Flotation**	
Liquid Control—Land	Existing Treatment Plants	**Filtration**	
Dikes and Trenches	**Chemical Reactions**		
Sorbents and Gels	Neutralization		
Liners	Precipitation		
Liquid Control—Surface Water	Coagulation		
Booms, Weirs, and Skimmers	Oxidation/ Reduction		
Water Sprays	Stabilization		
Sorbents			
Dikes, Sealed Booms, and Dredges			
Dispersants			
Diversion to Treatment			
Liquid Control—Ground Water			
Liners			
Movement Control (slurry trenches, grout, sheet piling, bottom seals)			
Plume Management			
Solids Control—Land			
Covers			
Sprays			
Containers			
Solids Control—Water			
Booms, Weirs, and Skimmers			
Dikes, Sealed Booms, and Dredges			

Stop Further Flow (contd)

- an explosion/implosion caused by pressure buildup
- a reaction of hazardous chemicals exposed to water, air, soil, or other chemicals and the formation of new hazardous materials
- danger to personnel at distances close enough to seal the container.

Contain Vapors and Gases

The best control method for vapors and gases is reduction of the vapor generation or release rate. Sealing the container (discussed above) is probably easiest. Evaporation from liquids may be reduced by cooling the liquid source or container with water, ice, dry ice, or liquid nitrogen. Evaporation also decreases when the surface area of the liquid is reduced. This can be accomplished by increasing the depth of the liquid or by covering the surface with sorbents or commercially available films or foams. Sorbents include straw or hay, fly ash, dirt, wool, and synthetics.

Control of vapors and gases in the atmosphere is usually not attempted because natural dispersion dilutes vapors and gases rapidly. Toxic vapors in enclosed spaces may be diluted by nitrogen or carbon dioxide purges. Fans and blowers can increase dispersion over small areas. Some compounds such as ammonia may be removed from the air by water sprays.

Possible consequences of the above mitigation methods include:

- contaminated runoff from water sprays
- large volumes of contaminated sorbents (which require proper disposal)
- the production of hazardous substances from reactions of chemicals and films, foams, sorbents, or from reactions of chemicals with nitrogen, dry ice, or water
- releases of hazardous chemicals as a result of container damage from freezing or water sprays
- explosions or fires sparked by mitigation actions in the presence of flammable vapors and gases
- danger to personnel from water sprays or exposure to toxic gases.

Contain Liquids on Land

The flow of liquid on land is usually controlled by trenches or by dikes. Dikes may be composed of dirt, sandbags, foamed polyurethane, or concrete. Gels and sorbents, including straw or hay, fly ash, wool, and synthetics are sometimes used to absorb liquids. Liners, such as clay, fly ash, low-permeability soils, soil-cements and lime-stabilized soils, concrete, asphalt, stabilized waste, and synthetics (PVC, hypalon, polyethlene) are used to protect the land surface and ground water.

Possible consequences of the above mitigation methods include:

- changes in drainage and erosion patterns
- contamination of soil in dikes or trenches
- contamination of sorbents, gels, liners, and dike materials (which require proper disposal)
- production of hazardous materials by reaction of the hazardous liquid and soil, water, air, dike materials, liners, sorbents, and gels, or by reaction of spilled liquids from different containers

Contain Liquids on Land (contd)

- movement of hazardous materials by seepage through dikes or trenches
- danger to personnel from equipment accidents or exposure to the toxic materials.

Contain Liquids in Surface Water

The mitigation methods chosen for releases of hazardous liquids into surface water depend on the density and solubility of the liquid. Liquids that float (such as oil) can be contained by booms and weirs and collected by skimmers. In some cases, water sprays can be used to control the spread. Sorbents can be used on some floating spills. Liquids that sink in water (such as PCB-bearing oil or chlorinated solvents) can be controlled by dikes and excavations under water, but must be collected by dredges or by draining the water body. If the hazardous liquid is about the same density as water, or if it is soluble, the liquid and the contaminated water must be sealed off or diverted and treated (either physically or chemically). Dispersants can be used on some chemicals to increase the rate of spread, reducing concentrations. Containment of liquids in water can be difficult because of wind, waves, currents, turbulence, and tides.

Possible consequences of the above mitigation methods include:

- toxicity associated with use of dispersants (depending on type, concentration, and rate of addition)
- disturbance of aquatic life by divers and boats
- increases in turbidity from sedimentation resulting from diking and dredging
- destruction of habitats caused by dams or diversions
- production of hazardous substances through reactions of the toxic liquid with sorbents and dispersants
- spread of contamination over a larger area by use of dispersants
- danger to personnel from equipment accidents or exposure to the toxic materials.

Contain Liquids in Ground Water

Control of contaminated ground water is extremely difficult and frequently not possible. Therefore, the best control method is prevention of percolation of hazardous substances into the ground water. This is usually accomplished through the use of liners (discussed above).

Contaminated ground water may be isolated by using bentonite slurry trenches, grout curtains, sheet pilings, and bottom sealing. These methods can be used either to seal off the bottom or side of the contaminated ground from ground-water movement or to seal off water supply sources from polluted ground water. In some cases, plume management techniques are used. Either contaminated water is pumped out and treated or disposed of, or clean water is injected into the aquifer to dilute the contaminant.

Possible consequences of the above mitigation methods include:

- production of hazardous substances by reaction of the contaminant with liners and grouts
- damage to underground containers and subsequent release of hazardous materials while excavating or drilling

Contain Liquids in Ground Water (contd)

- Increased movement through drill holes and reactions between chemicals in different damaged containers
- consumptive use of clean water (particularly of concern in arid areas where supplies are limited)
- production of large quantities of wastes from treatment
- danger to personnel from drilling or excavation accidents or exposure to the toxic materials.

Contain Solids on Land

Solids on land are controlled by covering the material; spraying the material with water, oil, or chemicals to reduce dust; lining the ground to prevent infiltration; building dikes to prevent contact with surface water; or placing in containers.

Possible consequences of the above mitigation methods include:

- contaminated runoff from water sprays
- soil contamination from oil or chemical sprays
- contamination of liners or covers
- soil contamination in dikes
- fugitive dust from increased moving of material
- production of hazardous substances through reaction with liners, covers, sprays
- danger to personnel handling the solids.

Contain Solids in Water

Solids in water can be controlled with much of the same equipment used for cleaning up liquids. Weirs, booms, and skimmers can be used for floating solids. Water sprays may be effective in containing floating solids. Sinking solids can sometimes be controlled by dikes or sealed booms, but must be removed by dredging. Suspended solids must be removed by physical separation methods, such as filtration.

Possible consequences of the above mitigation methods include:

- destruction of habitat by damming or diverting water
- destruction of benthos by dredging
- increasing turbidity by diking or dredging
- disturbance of aquatic life due to divers and boats
- danger to personnel from equipment accidents or exposure to the toxic materials.

CHEMICAL ALTERATION

Hazardous substances can be chemically altered to less hazardous materials by combustion, biological degradation, or chemical reaction.

Alter Hazardous Substances Through Combustion

Hazardous organic compounds can be destroyed by combustion. Open burning and controlled incineration are the common methods. Possible consequences include:

- production of toxic intermediate and by-product gases because of incomplete combustion
- production of ash

Alter Hazardous Substances Through Combustion (contd)

- air pollution from combustion and incineration products (particularly ash)
- contaminated water from scrubbers on incinerators
- explosions from uncontrolled or incompletely controlled burning or from variations in waste properties
- releases during transport of toxic compounds to incinerators offsite
- danger to personnel from explosions or exposure to toxic materials.

Alter Hazardous Substances Through Biological Degradation

Biological systems can be used to destroy a variety of organic compounds and mixtures. Although biological reactions are usually slower than chemical reactions, bacteria that are naturally present in the environment can adapt to degrade many chemicals. The addition of nutrients or specialized bacteria may speed up degradation significantly. Land-farming (spreading wastes on the soil to degrade) has been used commercially for oils and sewage wastes. Land-farming operating principles could be applied to a release site, or the toxic material could be shipped to an operating land-farm. Small-scale biological reactors can be used to treat waste from a particular incident. Some organics (if not toxic to the bacteria) could be degraded in existing municipal or industrial biological treatment plants.

Possible consequences include:

- persistence of toxic compounds during the long treatment and acclimation times
- production of toxic intermediates, by-products, and products, particularly by unwanted biological reactions
- residual toxic compounds (particularly heavy metals) in soil after biological treatment
- production of volatile or gaseous compounds
- production of sludge, possibly contaminated with toxic materials
- production of residual acclimatized bacteria in soil
- upset of biological treatment systems as a result of toxicity or overloading from excess oxygen demand
- releases during transport to offsite biological treatment systems
- danger to personnel from exposure to the toxic materials.

Alter Hazardous Substances Through Chemical Reactions

Reactions between hazardous substances and other chemicals can be very efficient and fast. The choice of chemical agents is limited by the chemical nature of the hazardous material.

Acids may be neutralized by alkali [limestone ($CaCO_3$), lime (CaO), hydrated lime ($Ca(OH)_2$), sodium carbonate (Na_2CO_3) or sodium bicarbonate ($NaHCO_3$)]. Limestone and sodium bicarbonate act as buffers and will not cause excessive basicity. Bases may be neutralized by acids [acetic (CH_3CH_2OOH), sulfuric (H_2SO_4), or hydrochloric (HCl)]. Acetic acid also acts as a buffer to prevent excess acidity.

Alter Hazardous Substances Through Chemical Reactions (contd)

Possible consequences of **neutralization** include:

- excess acidity or basicity as a result of insufficient mixing
- in-situ excess heat generation
- production of gases (especially using limestone reagent)
- precipitation of sludge
- high aqueous concentrations of the additives resulting in increased toxicity
- danger to personnel, particularly from handling acids and bases and from exposure to the toxic materials..

Heavy metals may be precipitated from water by alkali addition (to form metal hydroxides) or sulfide addition (to form metal sulfides). Precipitation may occur in conjunction with acid neutralization. Metal sulfides are usually less soluble than metal hydroxides, but the application of sulfides is harder to control. Sodium sulfide or hydrosulfide is usually used; iron sulfide has also been suggested.

Possible consequences of **precipitation** include:

- production of a sludge that increases turbidity and covers benthos
- disturbance of benthos and increased turbidity in the water column during sludge removal
- higher aqueous concentrations of calcium or sodium
- changes in pH, particularly during too-rapid alkali addition
- excess heat generation from too-rapid alkali addition
- formation of hydrogen sulfide during sulfide addition, or carbon dioxide during limestone addition
- dissolution of sludge and release of heavy metals if the pH changes (particularly under acidic conditions)
- danger to personnel, particularly from handling alkalis or sulfides.

Many chemicals, particularly organic compounds, can be oxidized in water by the addition of air, oxygen, ozone, hydrogen peroxide, or chlorine. A combination of ozonation and ultraviolet radiation has also been proposed for organic compounds. Oxidation at high temperatures and pressures (wet-air oxidation) is effective on many wastewaters. Other toxic substances may be controlled by reduction with ferrous sulfate or sulfur dioxide.

Possible consequences of **oxidation/reduction** include:

- production of toxic intermediates, products, or byproducts
- changes in dissolved oxygen and oxidation potential of the waterbody
- releases during transport of toxic materials to wet-air oxidation equipment offsite
- production of volatile compounds or gases by oxidation of organic compounds

Alter Hazardous Substances Through Chemical Reactions (contd)

- disturbance to aquatic life by gases during in-situ aeration or ozonation
- formation of foam or froth during in-situ aeration
- danger to personnel.

Liquids, sludges, and solids can be stabilized by inclusion in a solid matrix. A wide variety of processes and vendors are available. Most processes are based on cement/silicate chemistry, or on lime and pozzolanic materials (e.g., fly ash, cement kiln dust). Other processes use thermoplastic or organic polymers (polyester, vinylester-styrene, and urea-formaldehyde). Encapsulation in asphalt or plastics can also be effective.

Possible consequences of **stabilization** include:

- increased volume of waste requiring disposal
- incompatibility of hazardous material and stabilization chemicals, resulting in gas generation, side reactions, swelling and expansion, matrix dissolution, and failure to stabilize the toxic material
- decomposition or degradation and release of hazardous materials over time
- decomposition in the presence of acids
- danger to personnel from increased handling of the toxic materials.

Coagulation of solids in water may be effected by adding alum (aluminum sulfate), iron (ferrous sulfate or ferric chloride), calcium (calcium carbonate, oxide, or hydroxide) or polyelectrolytes.

Possible consequences of **coagulation** include:

- production of sludge, flocs, or froth requiring disposal
- excess alkalinity, excess heat generation, or gas production from calcium addition
- danger to personnel.

Many other reactions are possible. In general, possible consequences include:

- production of toxic or flammable products, by-products, or intermediates
- production of volatiles and gases in-situ
- production of solids or sludges in-situ
- changes in pH, dissolved oxygen, turbidity, and ion concentrations during reactions in water
- danger to personnel during handling of chemical agents.

SEPARATION

Separation methods are used to physically separate hazardous substances from the environment (usually water). The separated hazardous waste must be further treated or disposed of. These processes usually involve treatment equipment either onsite or offsite. Chemicals may be added to increase separation efficiency.

SEPARATION (contd)

Activated carbon (powdered or granulated) adsorption can be used to remove most organic compounds and some inorganic chemicals. Synthetic resins can be used instead of activated carbon. Inorganics, including heavy metals, are removed by ion exchange resins and by reverse osmosis, which is also used on some organics. Volatile compounds and gases may be stripped from water by air or steam.

Suspended solids may settle in thickeners or sedimentation basins where liquid flow rates are very low. Coagulants and flocculants are sometimes added to increase the settling rate. Dissolved-air flotation will force many solids to the surface. Filtration and centrifugation are used to separate liquids from solids or sludges. Fine solid particles can sometimes be separated by ultrafiltration. Skimmers are used to remove floating solids and dredges are used with sinking solids.

Possible consequences include:

- production of concentrated wastes requiring further treatment and disposal
- production of contaminated carbon, resins, and membranes
- contamination of equipment by hazardous materials
- production of contaminated gases during stripping
- reactions between hazardous materials and resins
- destruction of habitat and disturbance of aquatic life by pumping water through equipment
- changes in dissolved oxygen due to processing
- releases during transport to equipment offsite
- danger to personnel from working with concentrated wastes.

DISPOSAL OFFSITE

Hazardous substances are moved offsite for three reasons—for ultimate disposal in a secure landfill, for physical or chemical treatment, or for recycling to an industrial user or manufacturer. Landfill disposal is generally reserved for small amounts of hazardous material or for materials that cannot be easily treated. Recycling is preferable to landfill disposal but, in many cases, the hazardous material has been contaminated with soil, water, or other chemicals and cannot be used. Hazardous chemicals may also be moved to a temporary disposal site during an emergency response to reduce movement or exposure. For example, a chemical might be moved from an aquifer recharge zone to a secure landfill to prevent ground-water contamination, or from a heavily populated area to a rural area to reduce the possibility of human exposure.

Possible consequences of disposal or recycling include:

- changes in drainage and erosion patterns at the site after removal of contaminated soil
- destruction of ground cover during removal of contaminated soil
- changes in local water level because of removal of large amounts of contaminated water
- releases of hazardous substances during transport
- reaction between hazardous chemicals and containers or transport equipment

DISPOSAL OFFSITE (contd)

- corrosion and contamination of transport equipment
- process control problems during recycling—including process instability, impure products, and increased waste volume because of impurities (air, water, soil, other chemicals) in the recycle chemicals
- danger to personnel as a result of increased handling of the toxic materials

IMPACT ANALYSIS OF MITIGATION METHODS REFERENCES

The best references on mitigation methods and their environmental impacts for a particular incident or chemical release will be files and reports on similar releases. These files are typically kept by OSCs, Field Investigation Teams (FIT), Technical Assistance Teams (TAT), Regional Response Teams, and the Environmental Response Team. Other Federal, state, and local agencies may have files on emergency releases they have responded to. Chemical manufacturers, users, or transporters may also have useful information.

General references include conference proceedings, which usually discuss specific hazardous materials or incidents; scientific articles, which discuss specific materials or processes; and books and handbooks, which discuss treatment processes or cleanup techniques. Government publications cover almost all aspects of hazardous material management. Relevant references should be collected and read before an emergency develops. Examples of general references are given below.

Conference Proceedings

National Conference on Control of Hazardous Material Spills, U.S. EPA, 1972, 1974, 1976, 1978, 1980.

Land Disposal: Hazardous Waste, Proc. 7th Annual Research Symposium, EPA-600/9-81-002b, U.S. Environmental Protection Agency, March 1981 (and annually).

Management of Uncontrolled Hazardous Waste Sites, U.S. Environmental Protection Agency, October 1980.

Oil and Hazardous Material Spills, Information Inc., Silver Spring, Maryland, December 1979.

Industrial Waste Conference Proceedings, Purdue University (annual).

Scientific Literature and Magazines

American Society of Civil Engineers, Journal of Environmental Engineering Division

Chemical Engineering

Chemical Engineering Progress

Environmental Science and Technology

Journal of Hazardous Materials

Pollution Engineering

Government Publications

Hanson, W. G., and H. L. Rishell. 1981. *Cost Comparisons of Treatment and Disposal Alternatives for Hazardous Materials*, Vol. 1 and 2. EPA-600/2-80-188 and EPA-600/2-80-208, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Government Publications (contd)

Huibregtse, K. R., et al. 1977. *Manual for the Control of Hazardous Material Spills. Volume 1: Spill Assessment and Water Treatment Techniques.* EPA-600/2-77-227, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Malone, P. G., and L. W. Jones. 1979. *Survey of Solidification/Stabilization Techniques for Hazardous Industrial Wastes.* EPA-600/7-79-056, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Malone, P. G., L. W. Jones and R. J. Larson. 1980. *Guide to the Disposal of Chemically Stabilized and Solidified Waste.* EPA/530/SW-872, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Shuckrow, A. J., A. P. Pajak and J. W. Osheka. 1981. *Concentration Technologies for Hazardous Aqueous Waste Treatment.* EPA-600/2-81-019, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Tolman, S. L., et al. 1978. *Guidance Manual for Minimizing Pollution from Waste Disposal Sites.* EPA-600/2-78-142, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Books and Handbooks

Berkowitz, J. B., et al. 1978. *Unit Operations for Treatment of Hazardous Industrial Wastes.* Noyes Data Corp., Park Ridge, New Jersey. (Also available from NTIS as US EPA SW-148c).

Cheremisinoff, P. N., and F. Ellerbusch, ed. 1978. *Carbon Adsorption Handbook.* Ann Arbor Science, Woburn, Massachusetts.

CONCAWE (the oil companies international study group for conservation of clean air and water-Europe). 1981. *A Field Guide to Coastal Oil Spill Control and Cleanup Techniques.* (9/81). The Hague, The Netherlands.

CONCAWE. 1979. *Protection of Groundwater from Oil Pollution.* (3/79). The Hague, The Netherlands.

CONCAWE. 1981. *Revised Inland Oil Spill Cleanup Manual,* (7/81). The Hague, The Netherlands.

Culp, R. L., G. M. Wesner and G. L. Culp. 1978. *Handbook of Advanced Wastewater Treatment.* 2nd ed. Van Nostrand Reinhold, New York.

Melcalf and Eddy, Inc. 1979. *Wastewater Engineering: Treatment, Disposal, Reuse.* 2nd ed. McGraw-Hill, New York.

Metry, A. A. 1980. *Handbook of Hazardous Waste Management.* Technomic Publishing Company, Westport, Connecticut.

Perry, R. H., and C. H. Chilton, eds. 1973. *Chemical Engineers Handbook.* 5th ed. McGraw-Hill, New York.

Pojasek, R. B., ed. 1979, 1979, 1980. *Toxic and Hazardous Waste Disposal,* Vol. 1, 2, and 4. Ann Arbor Science, Woburn, Massachusetts.

Weber, W. J. 1972. *Physicochemical Processes for Water Quality Control.* Wiley-Interscience, New York.

Zajic, J. E., and W. A. Himmelman. 1978. *Highly Hazardous Material Spills and Emergency Planning.* Marcel Dekker, New York.

4.6 SPECIFIC REGIONAL INFORMATION

Information useful during an emergency response is of two types:

- Fundamental Technical Knowledge—This includes basic physical laws, properties, and processes that are universally applicable. The technical areas and considerations described in the previous sections fit into this category. Also included in this category are the references and contact points for obtaining information listed in the individual reference sections.
- Specific Regional Information—This category concerns specific people, areas, agencies, and industries within a particular region, and what assistance they can provide during an emergency. Included in this section are possible formats and procedures that may be used to locate and assemble this information. This section may be incorporated as part of the regional contingency plan.

Develop a Region-Specific Checklist

Because the problems, resources and appropriate responses vary from region to region, a checklist should be developed showing operating procedures and outlining the response whenever scientific support is needed. This checklist could be structured as in Table 4.9 (located at the end of this section).

Establish a Scientific Support Network

Because information needs during emergency situations may require the accurate and rapid acquisition of highly technical information, the scientific support will depend on the technical knowledge of individuals and organizations in the region. This will require establishing a network of scientific support.

Setting-up and maintaining a responsive network of scientific support requires the following:

- Someone within the Regional Office must have both the responsibility and the inclination to make the system work. This requires an active interest on the part of the Regional Administration.
- The establishment of close working relationships with individual technical contacts, on a person-to-person basis, is necessary.
- Steps to maintain interest in the program must be taken.

Maintaining sufficient interest and willingness on the part of unpaid individuals who are asked for help may be difficult. Some of the ways this can be accomplished are:

- Always reference the individual from whom assistance is obtained, by name and position. This applies both to written reports and to news releases.
- Acknowledge in writing any assistance obtained (include a copy to the individual's supervisor).
- Generate and distribute a periodic summary report of activities, describing incidents or other items of interest and referencing any assistance obtained.
- Offer and provide a "sounding board" for the opinions and ideas of the contacts. Encourage those that appear worthy.

Identify a Network of Scientific Advisors

Because the scientific-support network will in part be composed of key scientific advisors, these advisors should be identified and their

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Identify a Network of Scientific Advisors (contd)

cooperation enlisted. The identification of these should be coordinated with the RRT and mutual agreements should be reached on the sharing of advisors. The advisors may be located within or outside the region, but should be available for contact during a regional response. Such a list should be cross-referenced according to technical expertise, location, and the type of assistance that may be obtained. A possible format for organizing this information is shown in Figure 4.10 (located at the end of this section).

One method of identifying interested experts is to contact the editors of scientific journals, through which interested individuals could be solicited. This procedure has been used with success. Follow-up consisted of surveying the responders by using the format shown in Figure 4.11 (located at the end of this section). Once identified by name, location, and area of expertise, these scientists may be added to the list of key advisors.

Identify Resource Information Contacts

Some resource information contacts that should be investigated and included on this list are:

A. Federal

1) National Response Center
   USCG Headquarters
   Washington, DC
   (800) 424-8802 (24 hr)

2) Regional Response Center
   U.S. EPA Region

3) Environmental Response Team
   U.S. EPA
   Woodbridge Ave
   Bldg. 10
   Edison, NJ 08837
   (202) 321-6660 (24 hr)

4) USCG Marine Safety
   Offices and Regional Strike Teams
   U. S. Coast Guard District Offices

5) TECH ESCORT
   U.S. Army Technical Escort Center
   Aberdeen Proving Ground, MD 21010
   (301) 671-3601/2653 (duty hours)
   (301) 671-2773/4259 (nonduty hours)

6) National Transportation Safety Board

7) U. S. Department of Agriculture
   Regional Forest Services

8) Department of Commerce
   NOAA Regional Office

9) National Weather Service
   Silver Spring, MD 20910

Identify Resource Information Contacts (contd)

10) Radiological Assistance Team
U. S. Department of Energy
(301) 353-4093, 5486 (business hours)
(202) 252-6947 (business hours)
(301) 229-6026 (after hours)
(301) 552-9774 (after hours)
(703) 521-5707 (after hours)

11) Department of Defense
Army Corps of Engineers District Office

12) Department of the Interior
Regional Office
Bureau of Land Management
Bureau of Reclamation
Fish and Wildlife Service
Geological Survey District Offices
National Park Service

13) Department of Health and Human Services
Regional Office

14) Department of Justice by State

15) Department of Transportation Regional Office

16) Federal Emergency Management Agency
Regional Disaster Response and Recovery Division

17) Nuclear Regulatory Commission Regional Office

B. Technical Assistance and Industrial Response Teams

1) CHEMTREC
(800) 424-9300 (24 hr)

2) National Poison Center
(800) 228-9515 (24 hr)

3) National Chlorine Institute
CHLOREP (Chlorine Emergency Response Team)
(800) 424-9300 (24 hr)

4) Pesticide Safety Team Network
(800) 424-9300 (24 hr)

5) Explosives Emergency Center
(Railroad Emergency Response Team)
(202) 293-4048 (24 hr)

C. State Agencies

1) Poison Control Centers

2) Department of Health
a) Water Quality
b) Air Quality
c) Solid Waste Management
d) Drinking Water

3) Department of Natural Resources/Environmental Quality
4) Department of Transportation
5) Department of Fish and Wildlife
6) Department of Public Safety
7) Disaster/Emergency Services
8) Highway Patrol
9) Civil Defense

D. Local Agencies

E. Universities

Identify Laboratories, Consultants, Services

Before a response is required, governmental agencies, private laboratories consultants, and suppliers that could provide services during such a response should be identified, contacted, and educated to the need for their services. Laboratories should be certified and should demonstrate adequate quality control. Services of this type include:

1. Chemical analysis
   - laboratory, address, telephone number, contact
   - capabilities (organic qualitative/inorganic quantitative)
   - sample turn-around time
   - mobile labs
2. Bioassay/Toxicological Analysis
   - laboratory, address, telephone number, contact
   - capabilities
   - sample turn-around time
   - mobile labs
3. Geophysical Testing and Surveys
   - company, address, telephone number, contact
   - capabilities
   - response time
4. Impact and Risk Assessment
   - agency or company, address, telephone number, contact
   - Federal
   - state
   - private
5. Material and Equipment Suppliers
   - National Spill Cleanup Equipment Inventory System:

A national inventory of pollution response and support equipment (SKIM) has been developed to help OSCs and RRTs gain rapid access to resources during oil spill emergencies. A computer-based inventory system, SKIM is capable of supplying a list of cleanup equipment within a 300-mile radius from the response need. Response agencies may obtain this listing by calling:

U. S. Coast Guard
National Response Center
Washington, D. C.
(800) 424-8802

Identify Laboratories, Consultants, Services (contd)

Latitude and longitude of the location must be supplied. This information is also available from the U. S. Coast Guard District Offices.

- Region-Wide Contractors: Determine the equipment and personnel available as well as the mobilization time.
- Local Contractors: Many contractors have equipment (e.g., bulldozers, tractors, backhoes, electric generators, pumps) that may be useful in containment and removal operations. State offices of the Associated General Contractors maintain a membership list and generally are aware of where the equipment can be located.

During a response the most frequently used sorbents, hay and straw, are available from farmers, ranchers, stables, and livestock feed stores. Booms, skimmers, commercial sorbents, and contract services may be available from various sources within the region, which should be identified. Utility companies, lumber companies, pipe suppliers, irrigation or oil field supply companies, building supply companies, and hardware stores are possible sources of equipment and materials. State contingency plans often identify contractors and suppliers.

6. Waste Disposal Sites

The best method of disposal is to recycle or reuse the substances involved. If the recovered materials are relatively uncontaminated the manufacturer, shipper, carrier, or user may be able to use the substances involved in the incident. If the spilled material is contaminated beyond the point of recovery, permanent disposal will be necessary. Appropriate disposal sites available within or near the region should be identified during preresponse planning. The name, address, phone number, contact person, and area from which the material is accepted should be documented. These sites should also be categorized according to the type of waste accepted (e.g., hazardous). Often the following information must be supplied:

- material to be disposed of
- quantity of material
- type of containers the material is stored in
- circumstances requiring the use of the disposal site
- name, address, and phone number of the individual requesting disposal.

7. Licensed Waste Haulers

If the hazardous material must be removed from the site, a waste hauler will be needed. If the material must be moved across state lines, a company licensed by the Interstate Commerce Commission (ICC) to transport hazardous waste will be needed. Also, some states regulate intrastate movements. Before an emergency incident, the following information on waste haulers should be assembled:

Identify Laboratories, Consultants, Services (contd)

- Addresses, telephone numbers, contacts, availability of contact
- License classification, types of material, experience
- Disposal responsibility
- Capability, volumes hauled, special equipment.

J. J. Keller and Associates (1980)[a] have assembled a directory of hazardous waste services, including transporters. This directory is to be updated periodically. Other sources of this information are the notifications of hazardous waste activities prepared by EPA's Office of Solid Waste (e.g., EPA 1980[b]).

Determine the Availability and Location of Reference Information

Each region should have certain reference materials available, to be used in conjunction with scientific support activities. Some of the references should be immediately on hand for anyone involved in the coordination of technical support; at least a catalogue of sources should be prepared. As a guide, the catalogue should contain (for each reference) the following information:

1. Location
   - individuals—name and telephone number
   - libraries (in-house and public)
2. Availability
   - long-term loan
   - short-term loan
   - use only at the source
3. Portability
   - transportable
   - too bulky or sensitive for use in the field.

Certain source information such as base overlay maps should be maintained by the cognizant individual in charge of regional scientific support. Examples of these are discussed in earlier sections.

Identify Environmentally Sensitive Areas

As part of the preresponse planning, environmentally sensitive areas, critical habitats, and endangered species should be identified. The following format may be used for compiling this information:

State
A. Sensitive Area
   1. References
   2. Overlay Maps
B. Critical Habitat
   1. References
   2. Overlay Maps
C. Endangered Species
   1. References
   2. Overlay Maps

(a) J. J. Keller and Associates, Inc. 1980. *Hazardous Waste Services Director.* Neenah, Wisconsin.

(b) EPA. 1980. *Notification to EPA of Hazardous Waste Activities* (SW 897.10), Prepared by the Office of Solid Waste, U. S. Environmental Protection Agency, Seattle, Washington.

Develop a Regional Materials Inventory

Knowledge concerning the materials produced, stored, transported, and disposed of in the region will facilitate the planning of possible response actions. Use of base overlay maps or of the format outlined in Figure 4.12 can aid in identifying the types of materials that could be involved in an incident as well as the quantity and the probable location. Once these are identified, collecting pertinent toxicological, physical, treatment and disposal information about the materials and pertinent geological, hydrological and disposal information unique to the region is possible.

Establish a Format for Scientific Support Reports

The requirements and format of scientific support reports must be established on a regional basis. In general, such reports should contain the following elements:

1. Summary
2. Discussion of the problem
    a) introduction and background
    b) statement of the problem and discussion of items of interest (what makes it interesting, unique, or the same as others)
3. Method of Approach
    a) reasoning behind selection of approach
    b) documentation of the support that was provided (incorporate response plan)
    c) compendium of data statistics and logs that were collected.
4. Discussion—Narrative of what happened
5. Conclusions and Recommendations

These reports should describe the technical aspects of a response, rather than justify and document the total response effort. A sample outline of a scientific support report prepared by the emergency response team is shown in Figure 4.13.

TABLE 4.9 Checklist for Scientific Response Activities During an Emergency

1. What is the substance that was discharged?
   - Do you know the characteristics of the material?
     - chemical and physical properties
     - toxicological effects—short and long term
     - ability to transport in air, surface, and subsurface media.
   - Who is the manufacturer?
   - What is the potential quantity discharged?
   - Do you know individuals who are familiar with the material? Are they available for advice?
   - Where else can you find information on the substance?
   - How is the material normally produced, transported, and used; what impurities are expected and what is the effect of these?
   - What was the quantity discharged?
   - What analyses are appropriate, and how fast can they be obtained?
2. What was the location, date, and time of the release?
   - Was it a spill or leak, etc? Will it recur? Has it happened before?
   - Are population centers affected? What transport modes could affect these populations?
   - Are environmentally sensitive areas affected? What species are susceptible? At what concentrations?
   - Do you know the terrain and geology of the location?
   - Do you have meteorological and geohydrological data on the area? Are meteorological conditions predictable?
   - Where do you find this information?
3. What data are needed to document the case?
   - Have background samples been taken? Are they representative? Do prerelease data of the environmental quality exist? Are they readily available? Are they reliable?
   - What sampling and analyses are needed to document a) conditions before response efforts and b) the effect of cleanup actions?
   - Do other agencies have the data that are needed? Are they responsible for collecting them? If so, have they been made aware of the requirements for data validity and documentation?
4. Is scientific support required onsite?
   - Have you coordinated your time and schedule?
   - What should you take along? What information should be packed? Do you have contacts to check library information while you are in the field? Do you have notebooks, cameras, any needed sampling and test instruments?

TABLE 4.9 (contd)

5. Have you prepared a response plan?
   - Does the situation demand a specific plan, or will a generic plan work? When, how, and by whom will such a plan be prepared? What approvals are needed?
6. Have you taken steps to prepare a report on the incident?
   - Are you familiar with form and function of the report?
   - Who can help in preparing reports?
   - When and to whom are they due?
7. What surface waters are affected by the release?
   - Are drinking water or other critical water supplies affected?
   - Where will the material go, and how fast? Will it transform, dispense, or concentrate?
   - What water quality criteria apply? Can you predict the reach of the area not in compliance?
   - What data are needed to assess the impact?
8. What ground-water supplies may be affected?
   - Do you know how aquifers could be affected?
   - Are drinking water supplies endangered?
   - Do you know the water quality criteria for the material?
   - Can the time-concentration profiles be predicted? How does this compare with dose criteria for affected areas?
9. What actions are planned to mitigate the effects of the release?
   - Have potential impacts of the response actions been considered? Have known or suspected harmful effects been weighed against benefits?
   - Have alternatives been fully considered? Who can perform the needed risk analyses?
   - What are the special safety requirements?
10. What monitoring of the response is planned?
    - Is the cleanup/mitigation scheme working? Is anyone monitoring the effects?
    - Are there any plans for post-response monitoring? What are the assurances that key technical aspects of the release are included in such plans?
    - Is the mitigation process being documented? Are samples being taken during and after the efforts?
    - Is attention being paid to methods to assure completeness of the response?

FIGURE 4.10. Key Scientific Advisors

Technical Area - e.g., Biology, Chemistry, Hydrogeology

Name	Telephone	Organization	On-Scene Response(a)	Expertise	Comments

(a) That is, is the advisor willing to respond on-scene? yes or no

FIGURE 4.11. Scientific Interest/Capability Survey

SCIENTIFIC INTEREST/CAPABILITY SURVEY

1) Name and Address: _____

_____

_____

Business Phone: _____

_____

Home Phone: _____

2) Sponsoring Agencies: _____

_____

3) Alternate Person to be Contacted/Address:

_____

_____

_____

Business Phone: _____

Home Phone: _____

4) Is it likely that you will respond to the scene of a "critical" release as a result of your present interests and funding?

Yes ( ) No ( )

5) What are the major subjects of interest to you in connection with a release?

_____

_____

_____

_____

FIGURE 4.11. (contd)

6) Describe the geographic limitations, if any, of your area of interest

_____

_____

_____

7) If a release occurs within the subject and geographic limitations you have described, do you wish to be notified so that you can consider responding?

Yes ( )* No ( )

8) Do you wish to be notified at home if the occurrence is during nonbusiness hours?

Yes ( ) No ( )

9) Please describe any unique capabilities that you could provide which would be pertinent to assessing or predicting damage associated with releases of hazardous substances.

_____

_____

_____

*Note: Do not answer yes if you simply wish to gather statistics regarding releases, since these are regularly available through EPA Regional Environmental Emergency Response Team Weekly Incident Activity Reports and Semi-Annual Summary Reports.

FIGURE 4.12. Materials Inventory Example

Material: *Barfium Oozate*

1. **Producer:** *Oscar Mfg. Co., Portsmith, Florida*
2. **Quantities Produced:** *100 metric ton per week*
3. **Routes of Transportation:** *Rail-L&N, FL to Miami*
4. **Use Locations:** *Miami, Florida*
5. **Disposal Locations:** *Lake Okefenokee*
6. **Industrial Contacts**
   a. **Production:** *Mark Bark (000) 000-0000*
   b. **Use:** *N/A*
   c. **Disposal:** *Glop Disposal (200) 000-0000*

FIGURE 4.13. Scientific Support Coordinator's Report

I. SUMMARY
II. BACKGROUND
III. METHODS
   A. FIELD APPROACH
   B. LABORATORY APPROACH
IV. RESULTS
   A. FIELD STUDIES
   B. LABORATORY STUDIES
V. ANALYTICAL INTERPRETATION
VI. POST SPILL SCIENTIFIC SUPPORT ACTIVITIES
VII. FIGURES AND PHOTOGRAPHS